WIRELESS COMMUNICATION SYSTEM
NB-IoT

NB-SI2

Revision 1.0

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1 Introduction

This document describes features, parameters and setting possibilities of the NB-SI2 module, which is used for reading of either consumption meters with pulse output (water meters, electrometers, gas-meters...), or two-state sensors (e.g. door contacts, flood detectors, fire detectors, electronic seals...etc.) and for radio-transmission of the data from connected meters/sensors to the superior remote reading system via data services of NB-IoT 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-SI2 module can be used either for remote reading of one or two consumption meters with pulse output, or for monitoring of up to two two-state sensors. It is possible to combine both type of usage.

When using for **remote reading of consumption meters** (water meters, gas meters, electro-meters...), up to two meters with standard pulse ("SI") output can be connected to the module. The meters can be of different kind, with different quantities and units and with different conversion rates. The module continuously registers incoming pulses (generated by meters) into its internal counters, with using of preconfigured multipliers/divisors converts current status of each counter into the required output value and broadcasts info-messages with current statuses of connected meters in form of radio-messages of NB-IoT service provided by GSM operator (hereinafter „INFO-message").

When using for **remote monitoring of sensor statuses** (door contacts, flood detectors, fire detectors, electronic seals..), up to two two-state sensors with "off/on" ("0/1") outputs can be connected to the module. The sensors can be of different kind, with different type of output and different logic of signaling. The module continuously monitors status of each sensor and in case of change sends immediately alarm message (message of "TRAP" type) to the superior system. The module stores status of the input into internal counter and transmits information about the current status of connected sensors in regular INFO-messages.

Content of INFO-messages is configurable, it could contain current statuses of connected meters/sensors, current statuses of embedded temperature/humidity sensors, as well as previously measured "historical" readings stored in

the module memory. One message can contain **up to 24 historical readings**. Each message always carries identification and operational data of the module (processor temperature, battery voltage, signal strength information).

These messages are handed over to the application server with using of NB-IoT service of GSM provider. The data are transferred in form of standard IP/UDP packets, that are routed to the server of remote reading application operator through the designated Access Point of GSM provider. Application server receives the messages and performs their decoding, storing and further processing.

The NB-SI2 module supports **bi-directional communication** and it is able to receive through the network messages of "SET" type, generated by remote computer. These messages can be used for setting of module parameters from the remote server.

1.3 Hardware features and power supplying

The module is enclosed in humidity-proof plastic casing with IP65 degree of protection and can be used in interiors as well as in exteriors. The casing is designed for mounting on the wall or other construction element (beam, pipe...). Module can be treated with an additional sealing by high-adhesion silicon filling, that can ensure proof against inundation by water (IP68 grade). If this treatment is required from the manufacturer, it must be ordered separately.

The module is power supplied by internal battery with up to 10 years lifetime for frequency of 2 - 4 broadcastings per day (1 message can contain up to 24 readings). Battery lifetime can be negatively influenced by shorter broadcasting period, or by storing and operation in sites with the temperatures exceeding the recommended range.

The module is equipped with a SIM-holder for "Micro-SIM" (3FF) format of SIM-card (15 x 12 x 0,76 mm). SIM-holder is placed inside the module on the PCB. The module can be ordered with embedded SIM (eSIM) of chosen GSM operator.

The module can be controlled and configured either by configuration cable, or wirelessly - by infra-red remote control with using of optical converter. The module can be configured also remotely, with using of reverse channel of bi-directional communication.

External appearance of the NB-SI2 module is shown in the figure 1. Position of infrared sensor for wireless configuration is marked by green arrow. Newer module modifications are equipped with the special circular aperture ("peephole") for magnetic fixing of the optical converter.

Figure 1: View of the NB-SI2 module

2 Technical parameters overview

Overview of NB-SI2 module technical parameters is shown in the Table1 below.

Table 1: Overview of NB-SI2 module technical parameters

RF subsystem 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	GMSK, 8PSK	(adaptive)
Bandwidth	180	KHz
Transmitting power	200	mW
Receiver sensitivity	135	dBm
Communication protocol	NB IoT	(bi-directional)
Transmission speed	0,35 ÷ 240	Kbps (adaptive)
Antenna connector	SMA female	
Antenna characteristic impedance	50	Ω
Configuration interface RS232		
Transmission speed	9600	Baud
Operation mode	asynchronous	
Transmission parameters	8 data bits, 1 stop bit, none parity	
Signal level	TTL/CMOS	
Optical configuration interface		
Transmission speed	115 200	Baud
Optical band	870	nm
Optical interface specification	IrPHY 1.4 standard	
Pulse/sensor inputs		
Resistance of released contact	more than 10	MΩ
Resistance of short-circuited contact	less than 10	kΩ
Maximum input voltage	0,25	V
Maximum frequency of input pulses	300	Hz
Minimum pulse length	20	ms
Power supplying		
Lithium battery voltage	3,6	V
Lithium battery capacity	13	Ah
Weight and dimensions		
Length	145	mm
Width	45	mm
Height	100	mm
Weight	cca 300	g
SIM-card format	(15x12x0,76)mm)	„Micro-SIM”
Storage and installation conditions		
Installation environment (by ČSN 33 2000-3)	normal AA6, AB4, A4	
Operation temperature range	(-20 ÷ 40)	°C
Storage temperature range	(0 ÷ 40)	°C
Relative humidity *	95	% (w/o condensation)
Degree of protection *	IP65 or IP68	

* modules treated by additional silicon filling are waterproof with IP68 degree of protection.

3 Configuration of the NB-SI2 module

Configuration parameters of the NB-SI2 module can be displayed and changed from the common computer (PC) 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-SI2 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 3.3 „Remote setting of module parameters through the NB IoT reverse channel".

3.1 Setting of NB-SI2 module parameters by configuration cable

In following part of the document there is a description of these parameters of the NB-SI2 module, that can be displayed and examined from PC connected to the module by configuration cable. Some of the parameters can be changed by configuration commands entered „from the console".

3.1.1 List of NB-SI2 module configuration parameters and commands

List of all configuration parameters of the module can be displayed by entering of **"show"** command and pressing of „ENTER" key. The following list of parameters will display 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 8, Error 9
   Leak detection periode 12 hour(s), zero periode 30 minutes
  Input[1] ,multiplier 1,divider 1,mode falling, quick, alr:none, alarm code OK 8, Error 9
 Send periode : 120 min.
 Hist. periode : 15 min.
   in message 8 records, max. is 24 recs
 Send mask is 3 : I1, I2

 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 : 12
 SW version 1.07, date Mar  2 2020
mon#
```

List of all configuration commands ("HELP") can be displayed by entering of **"?"** command into the command line and pressing of „ENTER" key. The following list of commands will display in the terminal window:

```
mon#?
 Help :
 --- System commands ---
deb               : Show or set debug level
ta                : Show tasks
mb                : Show mail boxes
du addr           : Dump memory
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
 --- 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
server            : Server IP address
sport             : Server UDP port
sreply            : Send reply to server
apn               : Access Point Name
sess              : Set max session time in minutes
tshort            : Set modem short timeout
tlong             : Set modem long timeout
tconn             : Set modem connection timeout
info              : Show or set manuf. info string (0-30 chars)
tz                : Time offset in hours
ppm               : Set RTC 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
uptime            : Show uptime
sens              : Show sensors
reset             : Reset device
at                : Test modem
?                 : Show this help
mon#
```

Overview of configuration parameters with short description of their meaning can be also found in table 2 on the page 27. The meaning of individual parameters and detailed description of their usage can be found in the following part of chapter 3.1.

3.1.2 „System commands" group for control of module basic functions

This group of commands enables control of basic functions of the module. There are following commands:

reset	*command for module reset*
send	*immediate sending of radio message*
sendp	*immediate sending of series of messages*
sens	*show current values of internal sensors (temperature, voltage..)*
uptime	*show system uptime from last reset*
info	*setting of individual module description*

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 („out of turn") transmitting of the standard information message with measured values. This command can be used for checking of radio signal availability during the system installation, or for any adjustments and testing of the module. The command makes possible to send the information message anytime without necessity to change the transmission period or without waiting until the message will be sent spontaneously within the pre-set 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 watemeter shaft. Number of transmitted messages is set by parameter (number) after command, the first message is transmitted immediately 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 measuring physical quantities (battery voltage, 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 0
mon#
```

The **"uptime"** parameter value shows the time interval passed from the last device reset in seconds so that the exact moment of the last module reset can be recognized by this parameter. The parameter is of „read only" type. Example:

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

The **"info"** command can be used for setting of individual description/label of the module. Up to 30 alphanumeric characters can be entered. The label will be displayed in the „Info text" field of the optical configuration form. The label can contain any identification data (installation site code, customer code, meter serial number. Example of module individual text setting:

```
cfg#info 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 „Inputs" group parameters

This group of parameters and commands enables setting of internal pulse registers (counters) and setting of output values of the module.

The NB-SI2 module is equipped with two inputs (port 1 and 2), that are connected to the corresponding pulse counters (index 0 and 1). Each counter increases its value up one unit each time it receives pulse from a consumption meter connected to its port. Below listed commands are used for settings of the initial counter values and constants (multipliers, divisors) that can be used for adjusting of the output statuses to required values, and for setting of special function „leak" and „burst" for detecting of anomalies in the course of consumption (see detailed description in the paragraph 3.1.6 and 3.1.7).

Each input can be switched to so called **„alarm mode"**, in which after each change of input value the counter only changes its status (goes from "0" to "1" or vice versa) and the module transmits the message immediately with the change of status. Thus the module can read and transfer status information from **binary sensors** (e.g. door contacts, flood detectors..). Detailed description of setting of inputs in alarm mode can be found in the paragraph 3.1.8 „Settings of sensor inputs".

Setting of pulse inputs can be performed with using of following commands:

val[index]	*initial counter value setting*
mul[index]	*setting of multiplier (output value = status * multiplier)*
div[index]	*setting of divisor (output value = status / divisor)*
det[index]	*setting of trigger edge (0 - falling edge, 1 - rising edge)*
dmode[index]	*setting of pulse input mode (0 - quick pulses, 1 - slow pulses)*
alr[index]	*setting of alarm mode (sensor input setting)*
alcok[index]	*specification of alarm mode for "OK" status (sensor input setting)*
alcerr[index]	*specification of alarm mode for "Error" status (sensor input setting)*
leakp[index]	*period of leak detection setting (see „leak" function)*
leakz[index]	*zero interval of leak detection setting (see „leak" function)*
burstp[index]	*burst alarm limit setting (see „burst" function)*
burstt[index]	*burst measuring interval setting (see „burst" function)*
trf[index]	*setting of second input into the tariff switching mode (see „tariff" function)*

By using of **„val[index]"** command an initial (or actual) value of the counter can be set. After the value is setup, it increases from this value with each new-coming pulse. Actual counter value can be displayed by using of „val[index]" command (without parameter). Counter status can be set to required value by using of „val[index]" command followed by required whole number (integer).

Example of setting port No 1 (index=0) counter to "1892" value and follow-up checking of correctness of the configuration:

```
cfg#val0 1892
 Value[0] changed from 1565252980 to 1892
cfg#val0
 Value[0] : 1892 * 1 / 1 -> 1892
cfg#
```

It is evident from the example, that when checking of current status by „val[index]" command, the system displays not only current status value, but also current settings of multiplier and divisor and output value after multiplying/dividing.

By using of **„mul[index]"** and **„div[index]"** commands a value of multiplier and divisor can be set to the counter. Default setting of both values is "1". If it is necessary to adjust the counter value by some coefficient, enter convenient combination of multiplier and divisor as shown in example below.

Actual value of multiplier and divisor can be displayed by using of „val[index]", „mul[index]" or „div[index]" commands (without parameter) as shown in the example:

```
cfg#mul0
Multiplier[0] = 1
cfg#div0
Divider[0] = 1
cfg#
```

Multiplier and divisor setting example:

Watermeter generates measuring pulses after each 50 litres of consumed water. So as to indicate water consumption in m^3, it is necessary to adjust the original counter value by using of multiplier and divisor as shown in the example:

50 litres = 0.05 m^3, so to convert the value to m^3, it must be multiplied by 5/100.

It could be done by setting of multiplier to "5" and divisor to "100" - see example:

```
cfg#mul0 5
 Value[0] changed from 1 to 5
cfg#div0 100
 Value[0] changed from 1 to 100
cfg#val0
 Value[0] : 2000 * 5 / 100 -> 100
cfg#
```

*From the display of summary shown in the last sequence of commands it is evident that current status value (2000) will be interpreted as output value 100 (m^3). As one unit of the counter represents 50 litres, output value of the counter is: 2000*50 = 100 000 litres = 100 m^3.*

By using of **„det[index]"** command a trigger edge of the counter could be chosen. If it is preset to "0" option (default setting) the value of counter will increase with falling edge of incoming pulse (i.e. when the mechanical contact is short-circuited, or when an electronic pulse generator goes from "1" to "0"). If it is preset to "1" option, the value of counter will increase with rising edge of incoming pulse (i.e. when the mechanical contact is released, or when an electronic pulse generator goes from "0" to "1"). Actual value of trigger edge setting can be displayed by using of „det[index]" command (without parameter).

Example of setting of trigger edge for port No 1 (index=0) to "1" option (rising edge) and follow-up checking of trigger edge setting of all ports:

```
mon#det0 1
Det[0] = 1 - rising
cfg#det
Det[0] = 1 - rising
Det[1] = 0 - falling
cfg#
```

By using of **„dmode[index]"** command a smoothening (equalizing) filter of pulse input could be involved or disconnected. If it is preset to "0" option (default setting) the equalizing filter is switched off and the input is preset for detecting of high frequency (quick) pulses. If it is preset to "1" option, the equalizing filter that can suppress disturbing pulses on the input is switched on. This setting could be used if there are some parasitic pulses on the pulse input (e.g. if the input wire is too long), but using of this filter is restricted only for **sensor input**, or for detecting of **slow pulses** with maximum frequency of 2 Hz (minimum length of pulse is 250 ms).

Example of setting of port No 1 (index=0) mode to "1" option with involved equalizing filter (slow pulses):

```
cfg#dmode1 1
Mode[1] = 1 - slow
cfg#
```

Detailed description of „Leak" alarm function can be found in the paragraph 3.1.6 below. Detailed description of „Burst" alarm function can be found in the paragraph 3.1.7 below. Detailed description of sensor input settings can be found in the paragraph 3.1.8 „Setting of sensor inputs" below. Detailed description of „tariff switching" function can be found in the paragraph 3.1.9 below.

3.1.6 Description and setting of „Leak" alarm function

„Leak" function is used for detection of such situations in the consumption of gas, water or other liquids, when there are permanent low-quantity losses caused by minor leaks in the distribution system. In view of the fact that remote reading systems don't record consumption continuously but in some steps (usually given by full turn of its measuring disk), it could take quite long time until the trouble is discovered.

„Leak" function is based on the common pattern that during the normal long-term (e.g. day, week) operation there are usually some regular time intervals, when the consumption is in its „idle" status, because the gas/liquid is not consumed from natural reasons (e.g. during the night, or out of working hours). In these idle time intervals the consumption should be zero volume. If there are any leaks, time intervals with zero consumption practically either do not occur, or there are only short intervals caused by discontinuity of measuring system (e.g. if one metering pulse represents 100 litres, minor leak could become evident even after several hours, when such quantity will leak).

„Leak" function principle is shown in the figure 2. When setting of „Leak" alarm function the length of detection period must be entered by setting of **„Leak Detection Period"** parameter. After expiration of this period the system evaluates whether during this period at least one time occurred the situation, when the consumption was in zero level during preset time interval (entered by **„Zero Period"** parameter). If there is no leakage, it is highly probable that zero consumption period occur at least once during the period and system evaluates the period as „no alarm" status (see upper part of the figure 2). But if there is no one interval with zero consumption registered during whole detection period, module transmits to superior system „Leak" alarm message (see lower part of the figure 2).

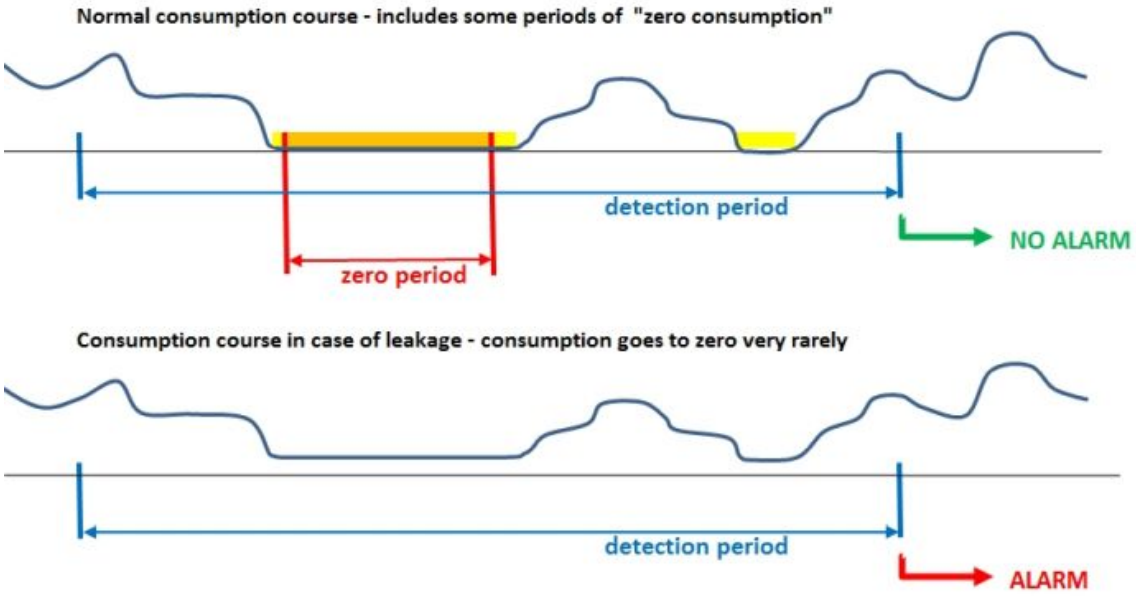


Figure 2: „Leak" alarm function principle

„Leak" function can be activated for chosen port by using of **leakp[index]** command that defines the length of detection period (**„Leak detection period"** parameter) in hours. By using of **leakz[index]** command setup concurrently for the same port the length of zero consumption interval (**„Zero period" parameter)** in minutes. If one of these parameters is set to "0" for some port, „Leak" function is deactivated for that port.

Example of setting **„Leak detection period"** parameter for port No 1 (index "0") to 24 hours value:

```
cfg#leakp 0 24
 Value[0] changed from 0 to 24
cfg#
```

Detection period can be set in range of 1 - 1090 hours, typical setting is 24 hours (daily operational cycle), or 168 hours (weekly operational cycle). Detection period starts running from module restart, or from the moment when the parameter is changed. Alarm message is sent at the end of detection period.

Example of setting **„Zero period"** parameter for port No 1 (index "0") to 60 minutes value:

```
cfg#leakz 0 90
 Value[0] changed from 0 to 90
cfg#
```

Zero consumption period can be set in range of 1 - 1090 minutes with precision of ten minutes (rounded to tens of minutes, e.g. 10, 20, 30...). If the command is entered with any other value (e.g. 36 minutes) the system will store rounded value anyway (in this case 40 minutes). General principle is that setting of zero period parameter to longer values means that the detection is more sensitive (it is capable to detect smaller leaks), but it is also less reliable with higher probability to produce false alarm due to real consumption caused by random changes of operating cycle (e.g. if somebody was held up at work few hours longer).

Setting of „Leak" alarm function parameters appears in the List of configuration parameters („show" command), in the section of the particular port:

```
Input[0] ,multiplier 0 ,divider 1 ,mode falling, quick, alr: none
  Leak detection periode 24 hour(s), zero periode 90 minutes
```

Structure of alarm message of „LEAK" type is described in the paragraph „Description of TRAP type message".

3.1.7 Description and setting of „Burst" alarm function

„Burst" function is used for detection of such situations in the consumption of gas, water or other liquids, when the burst consumption caused by broken pipe (or similar fatal failure of distribution system) occurs. If the consumption of liquid/gas is abnormally huge for some period of time, the module transmits to superior system „Broken Pipe" alarm message.

„Burst" function principle is shown in the figure 3.. „Burst" alarm function is set-up by entering of the **burst consumption limit** ("burstp[index]" command), that means the limit over which the consumption is considered as abnormal, and entering of **„Burst Check Time" period** ("burstt[index]" command) that means the minimum time period during which the consumption must be permanently over limit to detect the „Broken pipe" alarm.

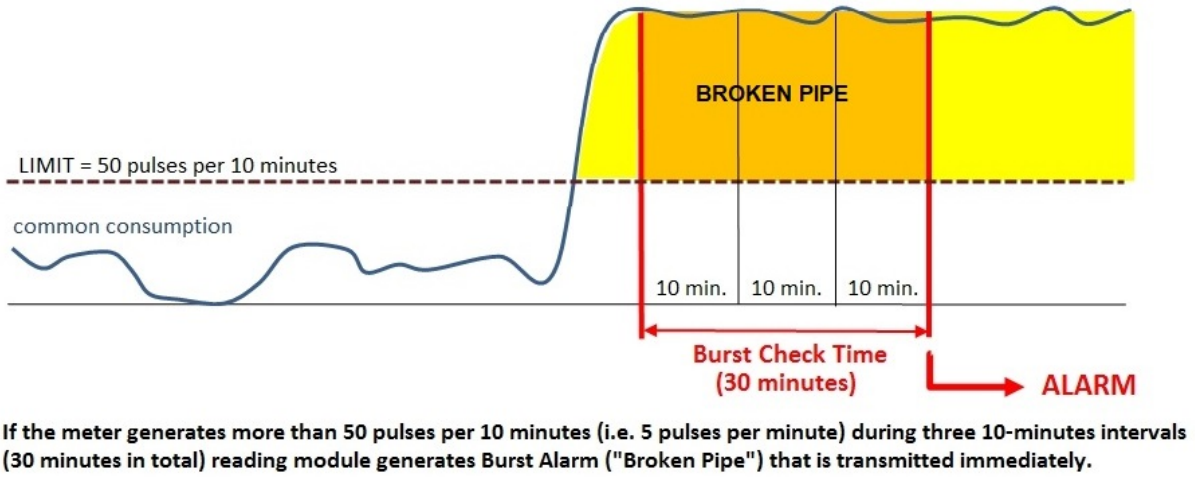


Figure 3: „Burst" alarm function principle

In view of the fact that different meters connected to the module could have different conversion rate of volume per measuring pulse, consumption limit is delimited universally as **number of registered pulses per 10 minutes time period**. Conversion table between „pulses per 10 minutes" and „consumption per minute" for frequently used conversion rates of watermeters is available in the figure 4.

„Burst" function can be activated for chosen port by using of **burstp[index]** command that defines required consumption limit in number of pulses per 10 minutes period. By using of **burstt[index]** command setup concurrently for the same port minimum duration of abnormal consumption („Burst Check Time") in minutes. If one of these parameters is set to "0" for some port, „Burst" function is deactivated for that port.

Example of setting **„LIMIT"** parameter for port No 1 (index "0") to 15 pulses per 10 minutes:

	"LIMIT" value [pulses per 10 minutes]											
	2	4	6	8	10	15	20	30	40	60	80	100
Conversion rate	**Limit flow [m^3 per minute]**											
0,001 m^3 / pulse	0,0002	0,0004	0,0006	0,0008	0,001	0,0015	0,002	0,003	0,004	0,006	0,008	0,01
0,01 m^3 / pulse	0,002	0,004	0,006	0,008	0,01	0,015	0,02	0,03	0,04	0,06	0,08	0,1
0,1 m^3 / pulse	0,02	0,04	0,06	0,08	0,1	0,15	0,2	0,3	0,4	0,6	0,8	1
1 m^3 / pulse	0,2	0,4	0,6	0,8	1	1,5	2	3	4	6	8	10
10 m^3 / pulse	2	4	6	8	10	15	20	30	40	60	80	100
100 m^3 / pulse	20	40	60	80	100	150	200	300	400	600	800	1000
1000 m^3 / pulse	200	400	600	800	1000	1500	2000	3000	4000	6000	8000	10000

Figure 4: Conversion table between "LIMIT" value and corresponding minute flow

```
cfg#burstp 0 15
 Value[0] changed from 0 to 15
cfg#
```

Consumption limit alarm value can be set in practically unlimited range (1 to 65535 pulses per 10 minutes).

Example of setting **„Burst Check Time"** parameter for port No 1 (index "0") to 40 minutes value:

```
cfg#burstt 0 40
 Value[0] changed from 0 to 40
cfg#
```

Minimum duration of abnormal consumption („Burst Check Time") can be set up in range 1 - 1090 minutes with precision of ten minutes (rounded to tens of minutes, e.g. 10, 20, 30...). If the command is entered with any other value (e.g. 36 minutes) the system will store rounded value anyway (in this case 40 minutes). General principle is that setting of Burst Check Time parameter to longer values means that the detection is more reliable, with lower probability to produce false alarm due to random changes in normal operation (e.g. during filling a tank with water), but in the same time it will prolong the response time between the breakdown and sending of alarm.

Setting of „Burst" alarm function parameters appears in the List of configuration parameters („show" command), in the section of the particular port:

```
Input[0] ,multiplier 0 ,divider 1 ,mode falling, quick, alr: none
  Broken pipe min. 15 pulse/10 min. during 40 minutes
```

Structure of alarm message of „BURST" type is described in the paragraph „Description of TRAP type message".

3.1.8 Setting of sensor inputs

Any two-state sensors of „on/off" (0/1) type with contact, relay, or electronic binary output (e.g. door contacts, flood detectors, fire detectors, electronic seals...etc.) can be connected to any of two NB-SI2 module ports. If the port is not preset to „alarm mode", the module only stores number of 0/1 transitions of the sensor into the counter and transmits the number in periodical info-messages. If, as an example, the door contact is connected to the port, the module registers each open/close cycle and regularly broadcasts number of cycles from last reset of the counter. If it is required to send a message immediately after each opening/closing of the door, it is necessary to preset the port (counter) into the **alarm mode**. For increasing of detection reliability it is recommended to involve **equalizing filter** for each sensor input as described above (see description of "dmode" command). By involving the filter, the detection will be more resistant to false alarms caused by any signal disturbances on the input wire.

„Alarm mode" can be activated for chosen port by using of **„alr[index]"** command, followed by parameter with 0, 1, 2 or 3 value. If **"0"** value is preset, alarm mode is switched off. If **"1"** value is entered, the input is switched to alarm mode and generates alarm in 1-to-0 transition (e.g. when the smoke sensor contact is switched on). If **"2"** value is entered, the input is switched to alarm mode and generates alarm in 0-to-1 transition (e.g. when the door are opened and the door contact is switched off). If **"3"** value is entered, the input is switched to alarm mode and generates alarm in both transitions (e.g. when the door is opened as well as when it is closed) .

Example of setting port No 2 (index "1") to "2" value, where the module transmits alarm when the sensor goes to "1" status (released contact), and follow-up checking of settings of all ports:

```
cfg#alr1 2
Alr[1] = 2 - rising
cfg#alr
Alr[0] = 3 - both
Alr[1] = 2 - rising
cfg#
```

As shown in the example, second port was switched to alarm mode with sending an alarm only in 0-to-1 transition (released contact). From the follow-up checking of all ports status (by using of "alr" command without index) it is clear, that there is the alarm mode with both announced transitions on the first port.

Alarm message always contains **actual status** after transition (value is "0" or "1") and a relevant **port identification**.

If some of the inputs is preset to alarm mode, each regular info message contains actual status of the connected sensor (OID 99, value "0" or "1" as well as counter value (OID 100) that carries information about the number of alarms from last counter reset.

From the NB-SI2 module point of view the "normal status" means "1" value on the input and "error status" means "0" value on the input. On basic (factory) setting the alarm messages are universally interpreted as „alarm status" (OID 60 value "5") and „normal status" (OID 60 value "4"), when **transition to alarm status** means change of input value from **"1"** (open contact) to **"0"** (closed contact). Even the module definition of normal and error status is fixed, by using of "alcerr[index]" and "alcok[index]" commands there is possible to preset outgoing alarm messages such way, that their meaning will be inverse (transition to module's "error" will be declared as "OK" and vice versa). Selection of suitable couple of alarm messages enables also more accurate description of the event.

Different (even inverse) meaning of **"1" to "0" transition** (closing of contact) can be preset by using of **„alcerr[index]"** command.

Different meaning of **"0" to "1" transition** (opening of contact) can be preset by using of **„alcok[index]"** command.

Change of meaning can be done by choosing of convenient couple of alarm codes (e.g. "Open" - "Close") and setting of these codes to both status transitions in accordance with real values on the module input. Actual list of alarm codes is available at the NEP Page website.

Current setting of alarm message interpretation codes can be found with using of the commands without parameter:

```
mon#alcok
AlarmOK[0] = 4
AlarmOK[1] = 4
cfg#alcerr
AlarmErr[0] = 5
AlarmErr[1] = 5
cfg#
```

Example of setting "9" and "8" alarm codes (door open / door close) for the first input:

```
mon#alcok0 9
AlarmOK[0] = 9
cfg#alcerr0 8
AlamErr[0] = 8
cfg#
```

After the previous change setting of alarm interpretation is as follows:

```
cfg#alcok
AlarmOK[0] = 9
AlarmOK[1] = 4
cfg#alcerr
AlarmErr[0] = 8
AlarmErr[1] = 5
cfg#
```

This setting will be displayed in the row of relevant input of the List of configuration parameters as follows:

```
Input[0],multiplier 1,divider 1,mode falling, quick, alr: rising, alarm code OK 9, Error 8
```

It is evident from the setting, that transition to "Error" status (1 - 0) on the "0" input will be interpreted in alarm message by "9" code (OID60, value 9 - see paragraph 3.4.3 „Description of TRAP type message") and the meaning of this code is "Closed". Transition to "OK" status (0 - 1) will be interpreted by "8" code, that means "Open".

3.1.9 Description and setting of „Tariff switching" function

When the „Tariff switching" function activated, all input pulses are carried only to the first input. **The second physical input** is connected to the tariff switching control voltage (see figure 5). Input pulses from the first port are alternatively switched to both counters in accordance with the tariff switching control voltage status, what means that during high tariff (t1) the pulses are directed to the first counter and during low tariff (t2) they are directed to the second counter.

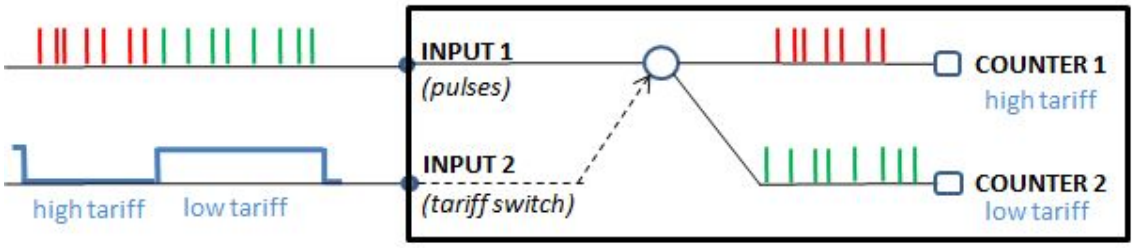


Figure 5: „Tariff switching" function principle

The function can be switched on by **trf[index]** command followed by parameter with 0, 1 or 2 value. Default setting with **"0"** value of the parameter means that the tariff switching function is disabled. By setting of **"1"** value the pulses are directed to the first counter ("t1") when the tariff switching control voltage on the second port is in "1" status („high", released contact). By setting of **"2"** value the pulses are directed to the "t1" counter during "0" („low", closed contact) status of control voltage (see figure). As only the second port of the NB-SI2 module can be used for tariff switching, the "trf" command should be always entered with index "1".

Example of setting port No 2 (index "1") to "1" value, when the module registers pulses to the first counter (t1) during "high" status of the tariff switching control voltage on the second port:

```
cfg#trf1 1
Change Tarrif[1] = t1 high
cfg#
```

Example of setting port No 2 (index "1") to "2" value, when the module registers pulses to the first counter (t1) during "low" status of the tariff switching control voltage on the second port:

```
cfg#trf1 2
Change Tarrif[1] = t1 low
cfg#
```

3.1.10 Commands for message content setting

This group of commands serves for setting of content of NB-SI2 module information message. There are following commands:

smask	*setting of content (selection of transferred information)*
hist	*historical readings storing period*
hdata	*displaying records in memory of historical readings*
fdata	*inserting records into the memory of historical readings*

The **"smask"** command can be used for setting of information message content. Message structure is described in "mask" table (see figure 6), where there are different masks in different rows (one mask in one row) and all transferred information of one particular mask are marked by "1" in corresponding column. Binary symbols 0/1

Mask	Humidity	Temperature	Pulse input 1	Pulse input 2
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
7	0	1	1	1
15	1	1	1	1

Figure 6: Table for selection of message content („mask")

from each four columns (Humidity, Temperature, Pulse input 1 and Pulse input 2) put together four-bit binary number. Decimal form of this number can be used as "smask" command parameter.

Required „mask" of message content can be entered by entering of mask decimal number (= number in "Mask" column) after "smask" command. Example:

```
cfg#smask 3
Send mask changed to 3 :  I1, I2
mon#
```

As it is clear from the example, in the messages with mask number "3" there will be transferred only values of both counters (without temperature and humidity information).

As NB-IoT services are typically charged per volume of transferred data, it is important to set appropriate message structure, that transfers only data that are really useful. If, as an example, only one sensor is connected to the module, it is senseless to transfer status of unused counter in each message.

Due to decreasing of broadcasting frequency (saving of battery lifetime) the module enables transfer of higher number of before read values in one message. In this case the message does not contain current values of meters, but it contains an array of previously performed readings, that were stored in module internal memory (hereinafter „historical readings"). Each set of historical readings is accompanied by the time of reading („timestamp") and this timestamp is also transferred to the central system. Memory volume enables storing **up to 24 historical readings**. Historical readings are stored into the memory with adjustable period, that should be proportionate to broadcasting period so as the message would contain no more than 24 historical readings. Memory of historical readings is cleared out after each message transmission

Example: *If broadcasting period is set to 240 minutes (4 hours) and historical readings storing period is set to 30 minutes, there will be 240/30 = 8 readings that will be stored during whole broadcasting period. In this case the transmitted message will contain an array of 8 historical readings.*

Current setting of historical readings will display in the configuration statement as follows:

```
Send periode : 60 min.
 Hist. periode : 10 min.
   in message 6 records, max. is 24 recs
 Send mask is 3 : I1, I2
```

It is clear from the abstract, that broadcasting period is 60 minutes, historical readings are stored every 10 minutes and each message contains only 6 historical readings.

The **historical readings storing period** can be preset by using of **"hist"** command followed by parameter. The parameter is required number of minutes. Allowed values of the parameter are 10, 15, 30 and 60 minutes (if other value entered, system will store nearest value). If the parameter is set to "0" (default setting), no historical readings are stored and only current values are transferred.

Example of setting of historical readings storing period to 30 minutes value:

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

The **"hdata"** command can be used for displaying of currently stored historical readings. Example:

```
cfg#hdata
History data :
2018-01-04, 13:30:00+01
 I1 : 1233
 I2 : 127
2018-01-04, 13:40:00+01
 I1 : 1249
 I2 : 129
2018-01-04, 13:50:00+01
 I1 : 1251
 I2 : 134
cfg#
```

As seen in the example, from last message transmitting there are three sets of historical readings stored in the memory.

The **"fdata"** command can be used for filling of fictive historical data into the memory. Required number of sets should be entered after "fdata" command. This command can be used only for module diagnostics or for testing of decoding system. Fictive historical readings contain zero values.

Example of command for storing of 5 sets of historical readings into the module memory:

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

Fictive historical readings can be checked by "hdata" command.

3.1.11 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-SI2 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.

3.1.12 Displaying of other operational entries in the list of parameters

In the lower part of the list of all configuration parameters there are some additional **identification and operational parameters of the module.**, that are of „read only" type. There are following parameters:

```
 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 : 12
 SW version 1.07, date Mar  2 2020
```

In the first part there is an information about sent messages. Parameter **"Next send"** means remaining time to the next broadcasting of info message. **"No. sent"** and **"No. recv"** indicate numbers of transmitted and received messages from last module reset.

In the **"Modem status"** section there are identification data of internal GSM-submodule (IMEI), unique number of inserted SIM-card (SIM CCID) and unique number of SIM-card user (IMSI). In the **"Last RSSI"** row there is an information about the signal strength of the last message received from the GSM network. In the **"Session count** row there is a number of sessions since last reset, in the **"Session timeout** row there is a current remainder of session timeout.

In the **"Conf. version"** row there is a current version (number) of configuration set, that increases with each storing of the configuration into the FLASH memory. The number is cleared by erasure of FLASH memory. In the **"SW version"** row there is a module software version and release date.

3.2 Setting of parameters by using of optical converter

The module i equipped with the „IRDA" infrared optical interface, that can be used for configuration through the **„USB-IRDA"** converter (USB-to-optic) or through the **„BT-IRDA"** converter (Bluetooth-to-optic).

All parameters that is necessary to set-up during common operation can be configured by **„USB-IRDA"** converter. The settings can be performed through the transparent casing without necessity to open the module's cover. This is the significant advantage especially if the module is used in humid environment and has been sealed by additional silicon filling (additional adaptation for IP-68 proofing).

Any changes in module's settings can be performed in **Module configuration table** that opens by click on the „Read device" button in „WACO OptoConf" program window. View of configuration table is depicted in figure 7.

In the **upper section of the table** there are „read only" type of parameters (factory settings) that refer to the identification of the module and its components.

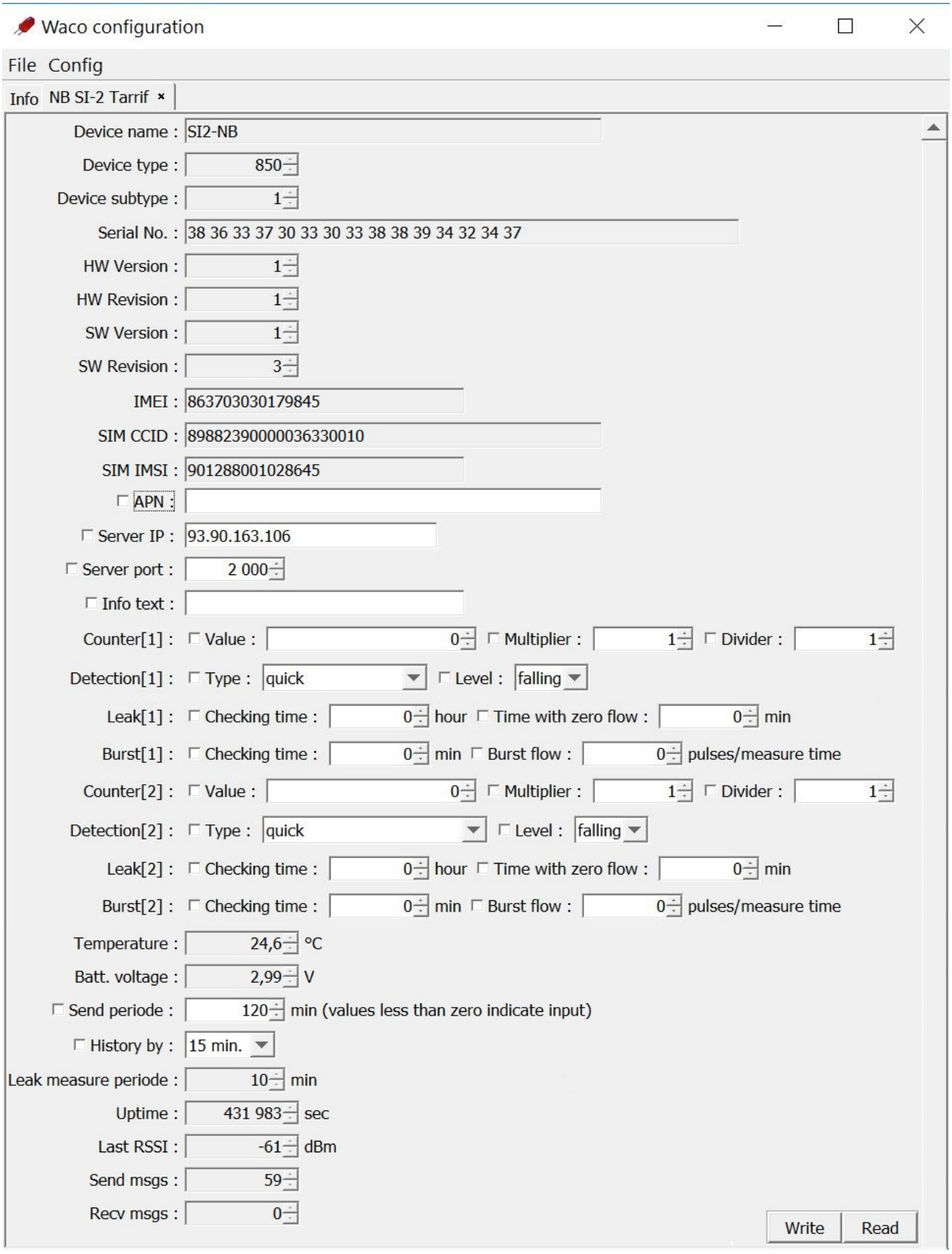


Figure 7: NB-SI2 module configuration table

There are following parameters:

Device name	*device name by manufacturer*
Device type	*device type by manufacturer*
Device subtype	*device subtype by manufacturer*
Serial No.	*device serial number (as well MBUS-ID in M-Bus address)*
HW Version	*hardware version by manufacturer*
HW Revision	*hardware revision by manufacturer*
SW Version	*software version by manufacturer*
SW Revision	*software revision by manufacturer*
EMEI	*unique identifier of internal GSM sub-module*
SIM CCID	*unique number of inserted SIM-card*
SIM IMSI	*unique number of SIM-card user*

All the parameters contain information about device identification, series and hardware/software version and are intended only for manufacturer's use.

In the **middle section of the table** there is a group of commonly used configurable parameters of the NB-SI2 module. There are following parameters:

APN	*name of network GateWay (Access Point Name)*
Server IP	*target server IP-address*
Server port	*target application port number*
Info text	*user defined device name*
Value	*counter initial value*
Multiplier	*multiplier of the counter (output value = counter value * multiplier)*
Divider	*counter's divisor (output value = counter value / divisor)*
Detection Type	*setting of equalizing filter and alarm mode*
Detection Level	*setting of trigger edge of the counter*
Leak check. time	*setting of "detection period" of the "Leak" function in hours*
Time with zero flow	*setting of "zero period" of the "Leak" function in minutes*
Burst check. time	*setting of "burst check time" of the "Burst" function in minutes*
Burst flow	*setting of "LIMIT" of the "Burst" function (pulses per 10 minutes)*
Send periode	*setting of info-messages transmitting period*
History by	*setting of historical readings storing period*

The first part of configurable parameters (**"APN", "Server IP"** and **"Server port"**) are parameters for setting of **route to target server and application**. More detailed description of these parameters can be found in the paragraph 3.1.11.

The **"Info text"**parameter is intended for setting of device user name/description. This setting is optional and has no influence on the module function. Value of this parameter displays only in this configuration table.

In the next part of the table there is a group of parameters for setting of internal counters, output values and alarms: **"Value"**, **"Multiplier"**, **"Divider"**, **"Detection"**, **"Leak"** and **"Burst"**. The NB-SI2 module is equipped with two ports (port 1 and 2), connected to corresponding pulse counters. Each counter increases its value with each incoming pulse. Above mentioned parameters can be used for setting of counter initial values, constants for adjusting of output values (multipliers and divisors) and setting of detection parameters. Editable fields are arranged into two sub-sections, each of them is intended for setting of one counter („Counter[1]" and „Counter[2]"). In each sub-section there are also variables for setting of alarm detection and criteria for „Leak" and „Burst" alarms for individual inputs.

The **„Value"** parameter is used for setting of the initial (or current) value of the counter. After this setting the initial value increases by one unit with each incoming measuring pulse.

The **„Multiplier"** and **„Divider"** parameters are used for settings of multiplier and divisor of the counter. The default setting of both parameters is "1". If it is required to adjust the output value of the counter by some constant (coefficient), enter the appropriate combination of the multiplier and divisor.

The **„Type"** parameter in "Detection" section is used for setting of equalizing filter on the counter input as well as for setting of alarm mode for the input. Parameter can be setup as follows:

- „quick" - equalizing filter disabled
- „slow" - equalizing filter involved for the input
- „slow+alarm falling" - involved filter, alarm message in "1-0" transition

- „slow+alarm rising" - involved filter, alarm message in "0-1" transition
- „slow+alarm both" - involved filter, alarm message in both transitions

Detailed description of these settings can be found in paragraph 3.1.5 („Inputs" group of parameters) and in paragraph 3.1.8 („Setting of sensor inputs").

The **„Level"** parameter in "Detection" section can be used for setting of counter trigger edge. "Falling" option means that the counter value will increase with falling edge of measuring pulse (i.e. short-circuiting of mechanical contact, or "1-to-0" transition of electronic pulse generator). "Rising" option means that the counter value will increase with rising edge of measuring pulse (i.e. releasing of contact, or "0-to-1" transition).

Variable **„Leak Checking time"** is used for setting of the length of „detection period" related to the „Leak" alarm function. Length of the detection period should be entered in hours. Variable **„Time with zero flow"** is used for setting of the minimal length of period with zero-consumption related to the „Leak" alarm function. Length of the zero consumption period should be entered in minutes rounded to tens (e.g. 10, 20, 30...). More detailed description of these variables and possibilities of their settings are explained in section 3.1.6 „Description and setting of the „Leak" function".

Variable **„Burst flow"** is used for setting of the upper consumption limit for the detection of broken pipe purpose („Burst" function). This limit should be entered in number of measuring pulses per 10 minutes (=constant measuring interval). Variable **„Burst Checking time"** is used for setting of minimal duration of over-limit consumption related to the „Burst" function. Length of this interval should be entered in minutes rounded to tens (e.g. 10, 20, 30...). More detailed description of these variables and possibilities of their settings are explained in detail in section 3.1.7 „Description and setting of the „Burst" function".

The **„Send periode"** parameter is used for setting of broadcasting period of regular information messages. Value of the period should be set in minutes. More detailed description of this variable and possibilities of its setting are explained in details in paragraph 3.1.11 „Commands for setting of message broadcasting system".

The **„History by"** parameter is used for setting of historical readings storing period. The parameter is set in minutes, allowed values of the parameter are 0 (=disabled), 10, 15, 30 and 60 minutes. More detailed description of this variable and possibilities of its setting are explained in details in paragraph refsection:param-msg „Commands for message content setting".

In the **lower section of the table** there are current values of internal sensors (temperature, voltage...) and other operational "read only" parameters.

There are following parameters:

Temperature	*current value of processor temperature (read only)*
Batt. voltage	*current value of battery voltage (read only)*
Leak measure periode	*measuring period of "leak" function (read only)*
Uptime	*elapsed time from last module reset in seconds (read only)*
Last RSSI	*signal strength of last message from GSM network*
Sent msgs	*number of transmitted messages from last reset*
Recv msgs	*number of received messages from last reset*

All these parameters are intended mainly for examination of module function and operation and for module diagnostics.

Some of the module parameters can be configured also by using of **„BT-IRDA"** converter and **„SOFTLINK Configurator"** mobile application. Current version of the NB-SI2 module supports configuring all parameters, that are necessary for module installation on the site, as well as performing basic tests.

In the figure 8 there is an identification form of NB-SI2 module (bordered by grey colour), form selection window (bordered by yellow colour) and administration form (bordered by blue colour).

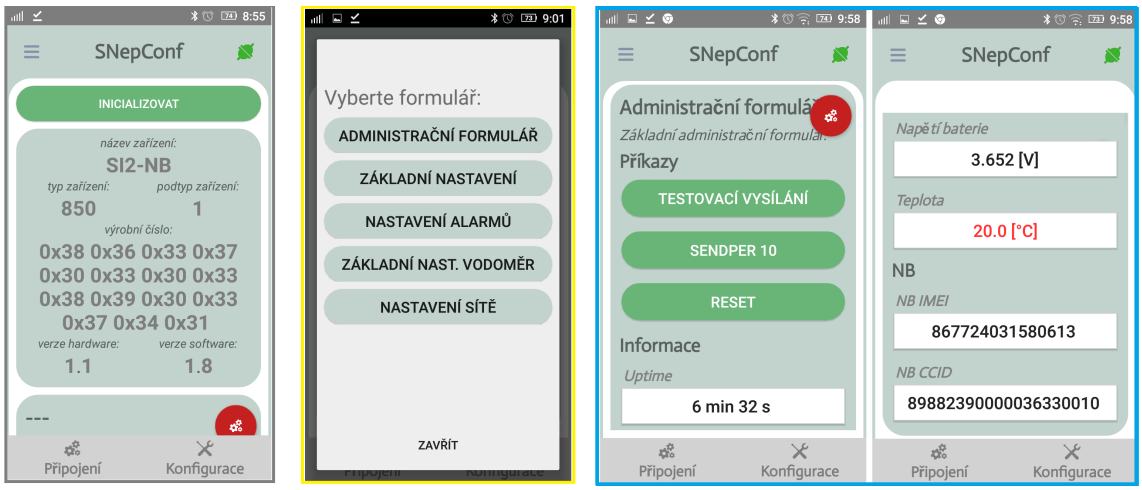


Figure 8: Basic forms of NB-SI2 module in „SOFTLINK Configurator" application

In the figure 9 there is a basic form for setting of inputs and outputs (bordered by red colour) and NB-IoT network communication setting form (bordered by green colour).

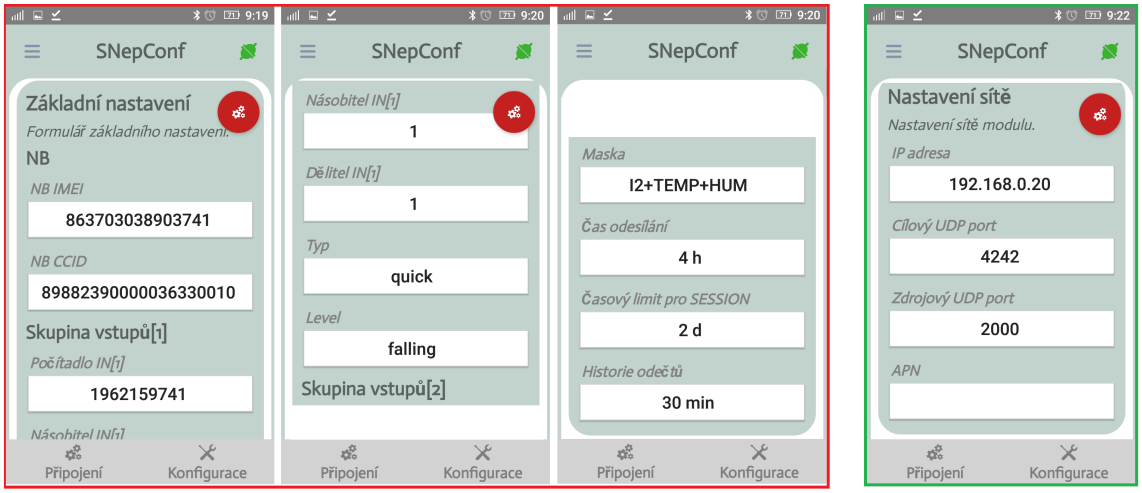


Figure 9: Input/output setting form and NB-IoT network configuration form

In the figure 10 there are special forms for typical using of the module in water supply engineering. In violet frame there is a form for setting of Burst and Leak functions, simple form for setting of single watermeter is bordered by brown colour.

Figure 10: Forms for setting of typical water supplying functions

As evident from the pictures, the application enables performing of following settings:

- setting of initial value, multiplier and divisor of inputs
- setting of trigger edge and mode of pulse inputs
- setting of message content (transferred value selection mask)
- setting of transmitting period of INFO messages
- setting of maximum session time with NB-IoT server
- setting of period of storing of historical readings
- setting of target server IP-address
- setting of target server UDP port number
- displaying of source UDP number
- setting of private network Access Point Name (APN)
- setting of Leak and Burst function parameters
- starting of one-time testing transmission
- starting of multiple (10 times) transmission series (SENDPER 10)
- sending of RESET command to the module

As the „SOFTLINK Configurator" application is continuously developed and improved, the screen previews of NB-SI2 module configuration forms can vary in time.

3.3 Remote setting of module parameters through the NB IoT reverse channel

NB-IoT network uses standard Internet Protocol (IP) that naturally enables data communication in **both directions**. The NB-SI2 module can use bi-directional communication for setting of its parameters from so called **"reverse channel"**, that is (for the reason of saving battery) opened only during two second period after transmitting of each message (INFO, TRAP, or RESPONSE). In this period the module's receiver is switched on and the module is able to receive message from remote server.

Messages in reverse direction can be used for setting of module parameters. As these **"setting messages"** are also coded by NEP protocol, they have in fact same structure, as the messages transmitted by module (i.e. set of NEP-coded individual variables inside UDP packet).

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

The NB-SI2 module performs setting of requested parameters (update requested variables) and sends back a message of the **"RESPONSE"** type (OiD 63 = **"4"**), that contains set of variables after requested update. The message is addressed either to the IP-address of the server from which the SET request came, or to the preset IP address of target server (depending on the setting of "Reply" parameter by "sreply" command).

Remote setting of parameters through the reverse channel can be used for setting of same parameters that can be set by optical interface (because both systems work on the same principle). More details about the reverse channel communication can be obtained from the producer upon request.

3.3.1 Overview of module configuration parameters

Overview of configuration parameters that can be used for user settings of the NB-SI2 module is shown in the Table 2 below. The parameters are presented in the same order as they appear in the List of all configuration parameters (see paragraph 3.1.1).

Table 2: Overview of NB-SI2 module configuration parameters

Item	Name	Type	Description	Default.
1	Timezone	number	Time zone (time from UTC)	1
2	Server IP	code	target server IP-address	
3	Server port	number	target application port number	2000
4	Reply	yes/no	setting of reply to the message from NB IoT 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	Session timeout	2 days
8	Multiplier	1 - 65535	Counter value multiplier	1
9	Divisor	1 - 65535	Counter value divisor	1
10	Mode	desc.	Filter and trigger edge setting	falling, quick
11	Alarm	desc.	Alarm mode setting	none
12	Alarm code	number	setting of alarm code for "OK" status	8
13	Alarm code	number	setting of alarm code for "Error" status	9
14	Leak period	0 - 1090	Leak detection period („Leak" function)	0
15	Leak zero time	0 - 1090	Zero consumption period („Leak" function)	0
16	Burst limit	0 - 65535	Alarm limit value („Burst" function)	0
17	Burst period	0 - 1090	Burst check time („Burst" function)	0
18	Send period	0 - 65535	Broadcasting period in seconds	3600
19	Hist. period	number	historical readings storing period	0
20	Send mask	number	number of message content mask	3
21	Encryption	code	Encryption key	indiv.
22	Next send	curr. status	Time to next message in minutes	read only
23	No. sent	curr. status	No of sent messages from reset	read only
24	No. recv	curr. status	No of received messages from reset	read only
25	Modem state	curr. status	internal GSM module status	read only
26	Session count	curr. status	number of sessions from rese	read only
27	Session timeout	curr. status	time to closing of current session	read only
28	Modem IMEI	curr. status	internal GSM module unique ID	read only
29	SIM CCID	curr. status	unique number of inserted SIM-card	read only
30	SIM IMSI	curr. status	unique number of SIM-card user	read only
31	Last RSSI	curr. status	signal level of last received message	read only
32	Version	curr. status	No of stored images since last FLASH erasure	read only
33	SW version	curr.status	version number and date of issue read only	

In the **„Type"** column there is a data type of the parameter. „Code" indication in this field means that the value is displayed in hexadecimal code (couple of hexadecimal characters means 1 Byte) with one exception - IP-address is indicated in common form (four decimal octets separated by dots). "Curr. status" indication means that the field contains current value of operational parameter that cannot be influenced. Range of numbers means that there could be a number from mentioned range.

In the **„Default"** column there are default (factory) settings of the parameter. Colour marking of this field has following meaning:

- green colour - commonly used parameters that should be set in reliance on the specific usage
- red colour - parameters that are not recommended to change
- grey colour - values that cannot be changed („read only")

Yellow colouring of the „Item" number highlights the parameters, that can be configured by using of **USB-IRDA optical converter** as described in details in chapter 3.2 „Setting of parameters by using of optical converter". These parameters can be set also remotely (from remote server) with using of NB-IoT reverse channel.

3.4 The NB-SI2 module data messages

3.4.1 Structure and types of data messages

The NB-SI2 module is intended for reading of connected meters/sensors and broadcasting of current statuses („readings") of the meters/sensors to the superior system via NB-IoT services of GSM operator.

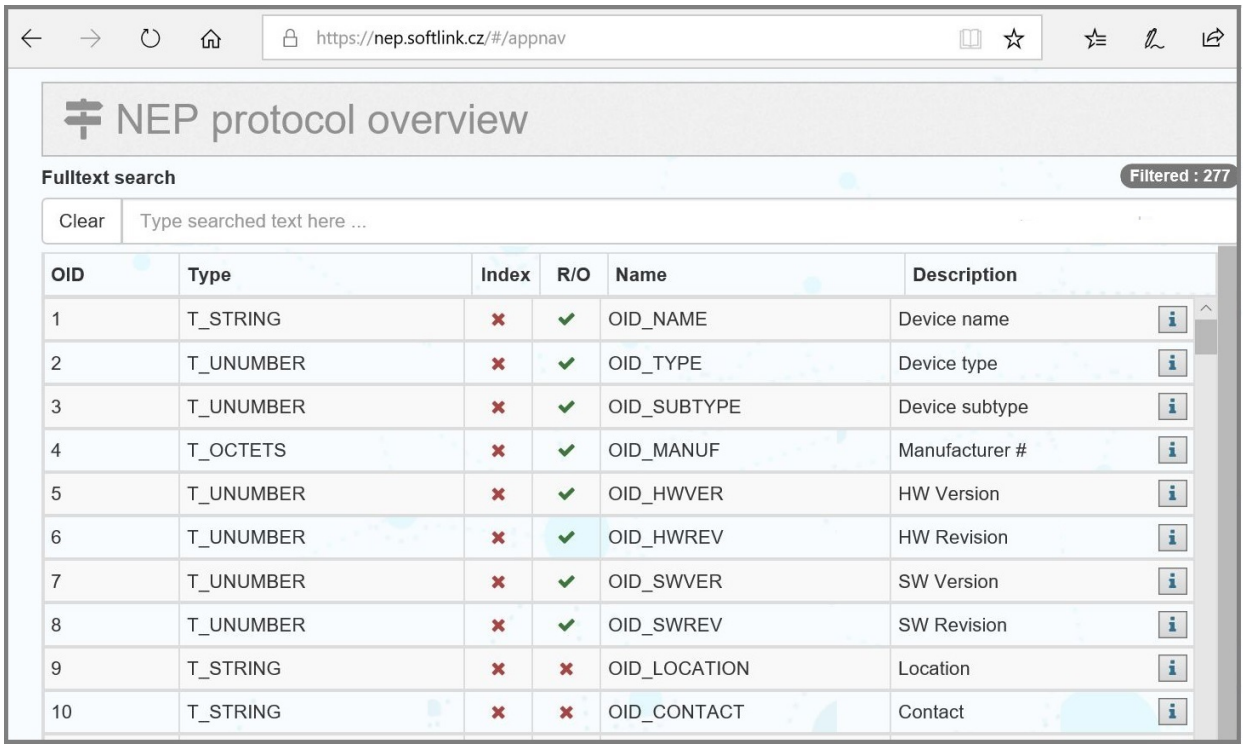
NB-IoT service utilizes for transfer of messages packets (datagrams) of UDP protocol (UDP = User Datagram Protocol), that is a transport layer of the Internet Protocol (IP).

Header of UDP datagram of the NB-SI2 module consists of three fields:

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

UDP header is followed by data content with all transferred variables.

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 11.



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 11: 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 NB-SI2 module message data content contains fixed part with identification and operational data and variable part with measured values. The module generates two basic types of messages:

- periodically transmitted **"INFO"** messages with current values of meters/sensors (readings)
- spontaneous alarm messages of **"TRAP"** type, generated immediately at alarm status (event)

The module generates these messages either in open, or in encrypted mode. Besides these basic types the module can generate also acknowledgment messages of „RESPONSE" type, as a response for setting messages from remote server (see paragraph 3.3).

3.4.2 Description of INFO message

Principal content of INFO message are statuses (readings) of meters/sensors, monitored by the module. Together with these readings there are also some identification and operational information of the module itself. The INFO messages are broadcasted in regular intervals preset by "periode" parameter (see paragraph 3.1.11).

Fixed part of the message is comprised of the first nine variables, that are contained in each message. In the table below there are marked in the OID field by yellow colour.

Variable part of the message contains set of measured values that depends on setting of the **message mask** by "smask" command. If only **current values** are transferred, the message contains only one set of measured values, without timestamps. If **historical readings** are transferred (see setting of "hist" parameter in paragraph 3.1.10 „Commands for message content setting"), the message contains several sets of measured values with appropriate **"timestamp"** before each set.

One set of measured values contains variables selected by "smask" command. Following variables can be selected:

OID 100/1 - status (output value) of input 1
OID 100/2 - status (output value) of input 2
OID 105/2 - temperature of embedded sensor (*)
OID 90/1 - humidity of embedded sensor (*)

(*) Only some module modifications are equipped with temperature and humidity sensors.

Example of INFO message data content of NB-SI2 module with **current values** and sending of all variables ("full mask"):

OID	Index	OID Name	Description	Example
63		Message type	Message of DATA/INFO type	6
2		Device Type	Type name by manufacturer	850
3		Device Subtype	Device modification	1
4		Manufacturer No.	Device identification (IMEI)	
12		Uptime	Time from last reset (sec)	186552
61		Sequence No	unique message number	
105	1	Temperature	Processor temperature in 0.1 °C	223
106	1	Voltage	Battery voltage in mV	3765
462	1	RSSI	Last RSSI value	-61
100	1	Input value 1	Counter 1 current value	1996
100	2	Input value 2	Counter 2 current value	12887
105	2	Temperature	Sensor temperature in 0.1 °C (**)	238
90	1	Humidity	Relative humidity in % (**)	3765

Example of INFO message data content of NB-SI2 module with **current values** and transferring only value of the first input ("minimum mask"):

OID	Index	OID Name	Description	Example
63		Message type	Message of DATA/INFO type	6
2		Device Type	Type name by manufacturer	850
3		Device Subtype	Device modification	1
4		Manufacturer No.	Device identification (IMEI)	
12		Uptime	Time from last reset (sec)	186552
61		Sequence No	unique message number	
105	1	Temperature	Processor temperature in 0.1 °C	223
106	1	Voltage	Battery voltage in mV	3765
462	1	RSSI	Last RSSI value	-61
100	1	Input value 1	Counter 1 current value	1996

Example of INFO message with **historical data** transferring data from both inputs (mask "3"):

OID	Index	OID Name	Description	Example
63		Message type	Message of DATA/INFO type	6
2		Device Type	Type name by manufacturer	850
3		Device Subtype	Device modification	1
4		Manufacturer No.	Device identification (IMEI)	
12		Uptime	Time from last reset (sec)	186552
61		Sequence No	unique message number	
105	1	Temperature	Processor temperature in 0.1 °C	223
106	1	Voltage	Battery voltage in mV	3765
462	1	RSSI	Last RSSI value	-61
*TimeStamp and data of the **first** historical reading*				
17		Timestamp	Reading time (Epoch Unix Time Stamp)	1549031954
100	1	Input value 1	Counter 1 current value	1984
100	2	Input value 2	Counter 2 current value	12832
*TimeStamp and data of the **second** historical reading*				
17		Timestamp	Reading time (Epoch Unix Time Stamp)	1549032854
100	1	Input value 1	Counter 1 current value	1985
100	2	Input value 2	Counter 2 current value	12873
*TimeStamp and data of the **third** historical reading*				
17		Timestamp	Reading time (Epoch Unix Time Stamp)	1549033754
100	1	Input value 1	Counter 1 current value	1998
100	2	Input value 2	Counter 2 current value	12905

As it is clear from the example in the table, each historical reading creates its sequence of variables in the message. The first variable in the sequence is reading date and time (TimeStamp) and this record is followed by read values valid for that reading.

Number of sequences depends on the number of historical readings stored in the module memory from the last message transmission, where there could be up to 24 historical readings (24 readings is a maximum limit done by memory volume).

If any input is set into the **alarm mode** (see using of "alr" command in paragraph **??**), the module sends in INFO-message input counter status (OID 100) as well asi **input current level** (OID 99), that is "1" or "0".

3.4.3 Description of TRAP message

Messages of TRAP type are used for immediate transmitting of information about event detected by the NB-SI2 module. The information contains type of detected event (e.g. "Processor temperature exceeded limit") that can be followed by one or several variables with parameters of the event (e.g. "Temperature" and "Temperature limit"). This way the message recipient get information about limit exceeding, accompanied by current temperature value and value of the limit.

Type of detected event is encoded into the **"Alarm code"** variable (OID 60 - TRAP CODE), where value of variable determines event type. Current version of the NB-SI2 module supports sending of events from connected devices (sensor events, "Leak" and "Burst" events) as well as its own events (module reset).

Fixed part of the message is comprised of the first six variables, that are the same as in INFO message. The only difference is that "Message type" (OID 63) is set to **"5"** value, what is a flag of **TRAP** type of message.

After this part of the message there is always **„Alarm code"** variable (OID 60 - TRAP CODE), carrying information about the event type. Current version of the NB-SI2 module supports following types of events:

- OID 60 - value"0" - event of "RESET" type
- OID 60 - value "4" - input in "OK" status - normal status (*)
- OID 60 - value "5" - input in "Error" status - alarm status (*)
- OID 60 - value "15" - input in "LEAK" status - alarm status
- OID 60 - value "16" - input in "NO LEAK" status - normal status (**)
- OID 60 - value "17" - input in "BURST" status - alarm status
- OID 60 - value "18" - input in "NO BURST" status - normal status (**)

(*) These types of events indicate alarm statuses on the pulse interface. Default values "4" and "5" generally indicate whether the port status is alarm or normal. With using of "alarm" couple of commands it is possible to make the event interpretation more specific according to the sensor real function (see setting of "alcok" and "alcerr" in paragraph 3.1.8 „Setting of sensor inputs".

(**) Positive events of "NO LEAK"/"NO BURST" type are generated in that case, when after one or several "alarm" periods a period without alarm status came around.

„Alarm code" variable can be followed by one or several variables specifying event parameters.

„RESET" type of event is followed by variable of **„Reset code"** type (OID 14 - RESET CODE), carrying information about the reset cause. In the NEP coding table there are following types of reset:

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

For all other event types is „Alarm code" always followed by **current port status** of the event input.

Example of "TRAP" message with information about the reset of "Warm start" type (caused by command):

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

Example of "TRAP" type message with information about the "LEAK" alarm on the first input:

OID	Index	OID Name	Description	Example
63		Message type	TRAP type message	5
2		Device Type	Type name by manufacturer	850
3		Device Subtype	Device modification	1
4		Manufacturer No.	Device identification (IMEI)	
12		Uptime	Time from last reset (sec)	186552
61		Sequence No	unique message number	
60		Trap code	LEAK alarm code	15
100	1	Input value 1	Value of counter 1	22618

3.4.4 Encryption of messages

Encryption of messages by AES key can be activated by setting of encryption key with using of **"ekey"** command (see paragraph 3.1.11 „Commands for setting of message broadcasting system"). Encrypted message is in its first variable („Message type") designated as „Encrypted message" (OID 63 value is **127** - ENCRYPTED MESSAGE). The first six variables of the message are always sent unencrypted, because they carry data that are necessary for decryption. All other variables are encrypted by **block cipher CFB** and they are transferred in the message as encrypted value of one variable, designated as **„Encrypted part of the message"** (OID 19 ENCRYPTED BLOCK).

Structure of encrypted message has following structure:

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

In the encrypted part of message there are all other variables encrypted by block cipher. The first variable in the encrypted block is always "Message type" (OID 63 MESSAGE TYPE), that carries an information, whether the type of message is INFO (value 6), or TRAP (value 5). Other variables follow in same order (and structure), as in unencrypted message (starting with seventh variable to the end of message).

4 Operational conditions

This section of the document describes basic recommendations for transportation, storing, installation and operation of NB-SI2 radio modules.

4.1 General Operation Risks

The radio modules are electronic devices power-supplied by internal batteries. The modules read counters or registers of the connected consumption meters or sensors.

During their operation be aware mainly of the following risks:

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-SI2/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 $(0 \div 30)$ °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-SI2 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 NB-SI2 module installation

NB-SI2 radio modules are enclosed in plastic casings with an IP65 degree of protection equipped with mounts for mounting on the wall, pipe or any other construction element. Input clamps, configuration connector as well as antenna connector are placed on the module's printed circuit board, so that it is necessary to open the casing to access these elements. The module is equipped with a "Micro-SIM" (3FF) format card holder placed inside the module on the PCB in standard delivery. Alternatively it can be ordered with embedded SIM (eSIM) of chosen GSM operator.

Modules with additional silicon filling (IP68 degree of protection) are delivered with embedded SIM-card (eSIM), mounted antenna, connected input signal cable and with battery switch in "ON" position. **It is recommended do not open the casing during operation until it is really necessary, and if so, do it very**

carefully. Configuration of the modules should be performed by USB-IRDA optical converter as described in section 3.2 „Setting of parameters by using of optical „IRDA" converter"

In the figure 12 there is displayed the NB-SI2 module dismantled into individual components

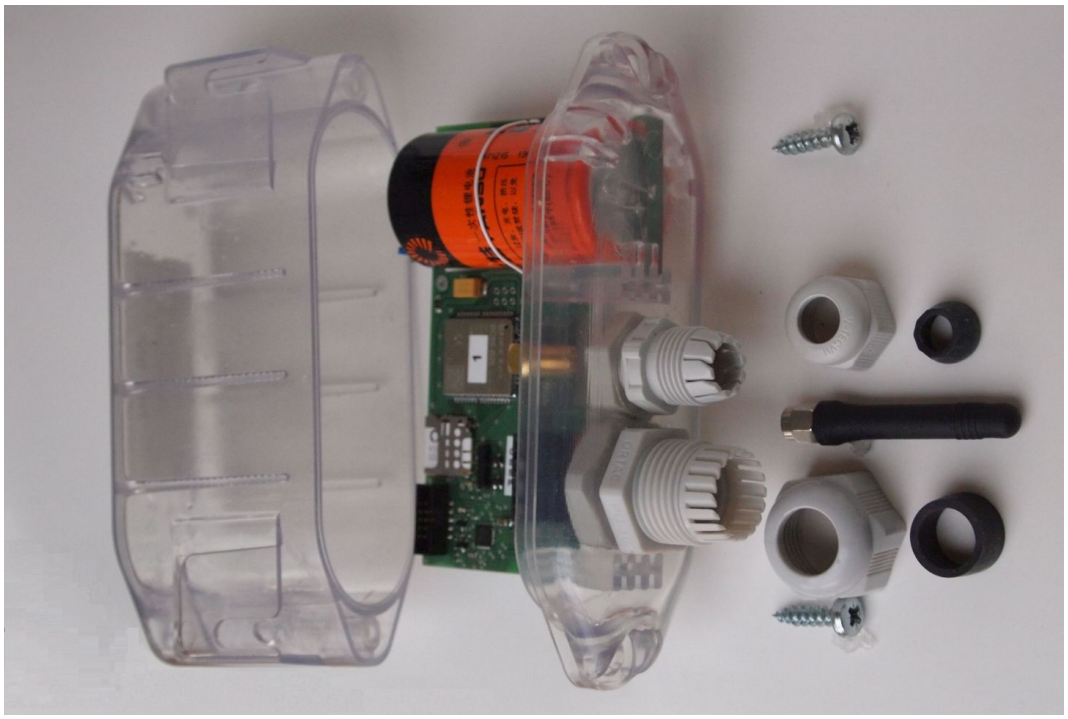


Figure 12: Set of NB-SI2 module components with stick antenna

In the figure 13 there is displayed the detail of NB-SI2 module printed circuit board with configuration connector marked by red colour, input clamps marked by yellow colour, SIM-holder marked by violet colour, antenna connector marked by blue colour and battery switch marked by green colour. Appearance of the module PCB could slightly vary in dependence on the module modification.

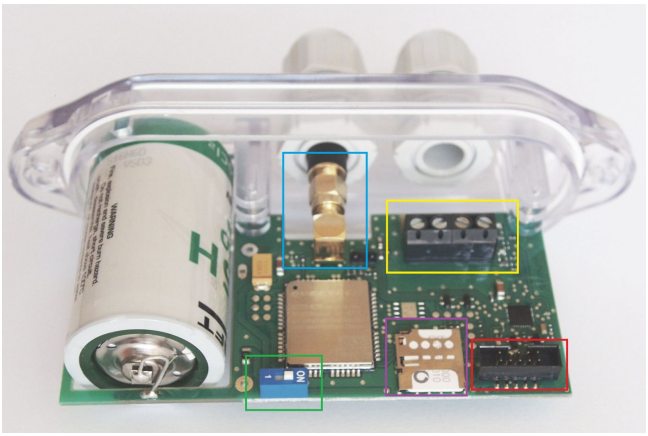


Figure 13: Detail of NB-SI2 module PCB

The case of NB-SI2 module consists of two parts:

- module base with the printed circuit board attached. It is the where the cable bushings are placed;
- box cap that covers the printed circuit board, with mounts for attaching of the module to the wall or other construction element

When mounting the device follow these instructions:

- attach the module to a suitable firm object (wall, pipe) by two screws or by a clamping tape. There are mounts by the box sides for the attachment. The recommended position of the mounted module is in the way that the base is down, cable bushings are facing to the floor;
- unscrew the screws on the sides of the module base (right beside the cable bushings), loosen the cap of the module and slide the base out of the cap (*);

- pull the cables with the outputs from the consumption meters or sensors through the cable bushing and connect the individual conductors to the input clamps of the module. The scheme of deployment and polarity of individual clamps is glued inside on the cap of the box. Make sure that the meters are connected to the relevant inputs according to the project materials or write down the diagram of individual connections;
- connect the local antenna (stick or rod type) or an antenna cable from a remote antenna into the antenna connector (coaxial connector on the printed circuit board beside the input clamps). Pull the antenna or the antenna cable through the cable bushings that is just right opposite to the antenna connector;
- switch-on battery by switching of micro-switch („jumper") placed on the PCB into the „ON" position. Some modifications of the module could be equipped with a pair of simple shortening pins, that should be short-circuited by shortening connector;
- perform an elementary module diagnostics and alternatively go through the module configuration (setting of parameters) with using of configuration cable as described in chapter 3 „Module configuration". In case the module has been fully pre-configured in the preparatory phase of installation, at least check and set-up input/output values to ensure that the information sent in the radio-messages will be correct;
- tighten the nuts on the cable bushings to seal them and protect the cables from unwanted pulling out of the clamps;
- insert the base back into the cap and fix with screws. For the mounting in a humid environment it is recommended to apply silicone sealant on the outer perimeter of the seating edge of the base before screwing the box back together;
- if the internal rules or the mounting process needs the antifraud seal to be installed (as the protection from the unwanted influencing), stick the antifraud seal across the joint between the two parts of the box.

(*) ATTENTION! *If the module is sealed by additional silicon filling with IP68 degree of protection do not open its casing during the installation! Meter outputs can be connected to appropriate wires of the input cable (that had been connected to the module before silicon filling) and configuration could be performed by radio or by using of an optical converter USB-IRDA.*

If the module is rated in IP65 or IP68 degree of protection, this declaration is valid only under condition of the proper mounting and sealing. When assembling the modules with IP68 degree of protection that will be placed in the humid environment, it is necessary to follow these rules:

- both cable bushings must be properly sealed;
- the joint of both parts of the box must be properly sealed by original rubber sealing).

After the mounting, write down the counter values of all consumption meters connected to the module into the mounting sheet and alternatively once again check out the module's functionality and the correctness of output values (which must correspond to consumption meter mechanical counters). Test the module functionality by „end-to-end" method, that means by checking of the readings directly in the central system of remote reading.

Follow the consumption meter manufacturer's instructions for determination of the length of the connection cables between the consumption meters and the radio modules.

When locating installation site, selecting antenna type and antenna position it is necessary to take into account conditions for radio signal propagation in the area of installation as well as protection of the device against possible mechanical damage. The radio-signal conditions can be estimated empirically on the base of previous experience, or examined by measuring of the signal strength by the reference transmitter/receiver.

4.7 Module and meter replacement

When there is necessary to replace the module due to the module failure or due to battery discharging follow this procedure:

- check the antifraud seal before dismantling – the antifraud seal damage must be solved according to the internal rules of the customer/project;
- unscrew two screws on the sides of the module base (beside the cable bushings), loosen the cap of the module and slide out the base from the cap;
- disconnect the cables from the consumption meters from the input clamps, alternatively disconnect the cable of the external antenna from the antenna connector;
- by switching of micro-switch („jumper") placed on the PCB into the „OFF" position (or replacing of shortening connector from shortening pins) disconnect the module from the battery power supply;
- loosen the fixing screws (or clamping tape) that hold the module on the wall, pipe or other pad and dismantle the cap;

- put both parts of the module back together by screwing the cap together with base (*). Mark the module visibly as „defective", alternatively you can fill in the form (mounting report) about the module replacement;
- install a new module in the same way as described in paragraph 4.6 above. Pay attention to the correct connection of the input cables (must be the same inputs as they were on the original module) and set up the relevant configuration parameters, namely broadcasting period and input/output values.
- write down the serial number and seal number of the module, alternatively also actual statuses of counters of connected meters;
- if possible, arrange making of all appropriate changes in the database of the remote reading system immediately.

(*) CAUTION! *The type label with the module serial number is always on the cap of the module so the base and the cap of the module must always be one whole unchangeable unit. Always pay attention to the completing of the correct cap with the correct base of the module, that is the reason why it is always necessary to replace the whole module – the base and the cap together. The correct module completion can be checked out according to the auxiliary label with the serial number glued on the PCB.*

When there is necessary to replace a consumption meter connected to the module due to the meter failure, expired metrology period or for any other reason, follow this procedure:

- check the antifraud seal before dismantling – the antifraud seal damage must be solved according to the internal rules of each customer/project;
- if the module is sealed by additional silicon filling with IP68 degree of protection do not open its casing! Disconnect replaced meter from the input cable and connect new meter to the same wires;
- if the module is in common IP-65 design, unscrew two screws on the sides of the box (beside the cable bushings), loosen the cap of the module and slide out the base from the cap;
- switch off battery, disconnect the cables from replaced consumption meter from the input clamps, replace the consumption meter and connect its cable back into the input clamps;
- switch on battery, perform setting of input/output values of the relevant input (*) according to the instruction in the chapter 3 „Module configuration". Check out the correctness of output values (which must correspond to consumption meter mechanical counters) by checking of the readings directly in the remote reading system.
- fill in the required documentation for the meter replacement (mounting sheet), precisely write down the value of the mechanical counter of the new meter;
- cover the module and, if needed, apply the sealant according to the instructions in paragraph 4.6. Alternatively wait for the first reading and cover the module afterwards.

(*) CAUTION! *The new meter might require a different setting of module's input/output even if the meter is the same type and manufacturer. Conversion constants can differ from each other even in various modifications of the same type of the meter.*

4.8 Module dismantling

When dismantling, open the module, switch off battery, disconnect cables and dismantle the cap from the wall, pad or pipe. Put the module parts back together by mounting of the cap on the module base. After the dismantling mark the module as „dismantled" and fill in the relevant documentation, prescribed for this situation by the internal rules. If possible, arrange deactivation of the module in the database of remote reading system immediately.

4.9 Functional check of the module

After putting the module into operation (or after each repair and replacing of the module) it is recommended to check basic functions of the module as follows:

- check setting of basic module parameters, especially broadcasting parameters (encryption, broadcasting period, routing information) as described in paragraph 3.1.11;
- after connection of input cables from connected meters/sensors check correctness of reading input pulses by repetitive inspection of counter current values through the configuration cable (by using of "val" and "sens" commands), or reading of "Value1" and "Value2" parameters by using of optical converter (by "Read" button). If there is a real consumption in progress on the measured volume or energy, counter values should change in correspondence with changing of values on mechanical counters. Values of physical quantities (temperature, voltage..) should correspond with reality;

- examine coverage of installation site with NB-IoT radio-signal by sending of several messages with using of "send" command as described in paragraph 3.1.2„System commands group for control of module basic functions" and their receiving in the remote reading system. Some indication about the NB-IoT signal availability can be obtained by checking of RSSI value in the list of configuration parameters, or "Last RSSI" value in the optical configuration table; i
- perform complex (end-to-end) check of implementation of the module into the remote reading system by inspection of data rendered by module in reading system database. If the module broadcasting period is quite long, use test broadcasting function described in previous item.

4.10 Operation of the NB-SI2 module

The NB-SI2 module performs readings and broadcasting of radio messages fully automatically. The greatest risks of permanent breakdown of module broadcasting are commonly caused by human activities within the installation site, especially mechanical damage of the module, excessive humidity or water inundation, or shading the RF signal by metallic object due to building operations.

To eliminate these risks, it is recommended to pay close attention to selection of the installation site and choice of antenna and antenna location so that to find appropriate compromise between qualities of signal and the level of risk of module mechanical damage. It is necessary to carry out the installation carefully with using of high-quality cables and mounting components.

To prevent an unexpected breakdown, it is recommended to perform regular monitoring of all broadcasting data, i.e. readings, processor temperature and battery voltage. If some of the parameters goes beyond the common steady value, it is recommended to contact the installation site caretaker and ask for the potential cause of the anomaly or perform the physical check on the installation site.

The risk of **premature battery discharge** could be eliminated by respecting the instructions described in paragraph 4.1.2.

4.11 Using of NB-SI2 module for remote monitoring of sensors

The NB-SI2 module can be used also for remote monitoring of any two-state sensors with either isolated contact (e.g. mechanical contact, relay, reed contact...), or solid-state relay, or open collector types of outputs. It is not possible to connect a sensor with its own source of voltage on its output. Convenient types of sensors are displayed in the Figure 14.

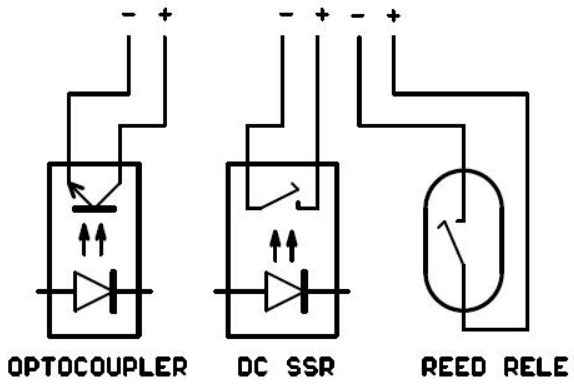


Figure 14: Types of sensor outputs convenient for NB-SI2 module

When using of sensor with „open collector" output (see „optocoupler" in the Figure 14 left), it is necessary to observe its +/- polarity as marked on the module's and sensor's labels. When using of sensors with solid state relay output (see Figure 14 in the middle), or with isolated contact (see Figure 14 right), the polarity is usually not important.

Sensor output should be connected to the module's input clamps same way, as consumption meter. It is recommended to use shielded cable with minimum length.

Setting of sensor input is described in detail in paragraph 3.1.8 „Setting of sensor inputs". Before setting it is necessary to realize, in which state the sensor output is switched off, and in which state it is switched on, and which status should be propagated as „alarm message". If, as an example, the monitored sensor is a security loop (electronic seal - see Figure refimg:sensor-seal), it is clear, that in „normal" status the contact is switched on,

because the contact head is coupled with magnet segment. In this case the primary cause of alarm status should be opening of security loop that causes detachment of contact head from magnet and releasing of reed contact inside the head. Releasing of contact is detected as rising edge (”0-to-1” transition) so that the alarm mode should be set to ”2” (”rising”) value. If the loop (or cable) is torn, the result would be the same.

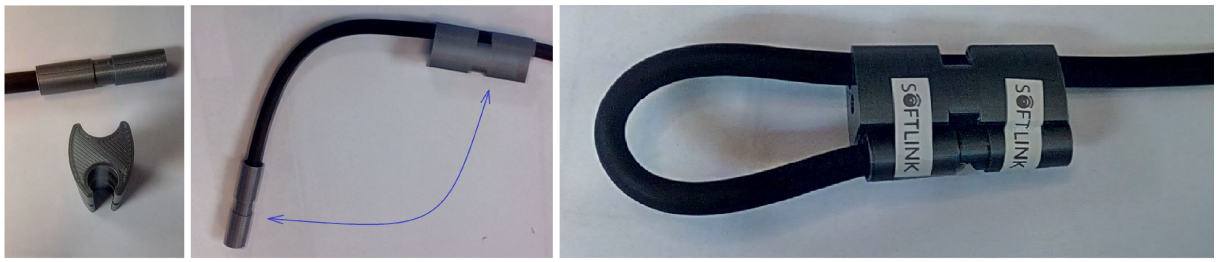


Figure 15: Principle of „electronic seal” sensor

If the subject of monitoring is opening of doors with using of position sensor. (see Figure 16), setting of alarm mode depends on the manner how the sensor was mounted on the door (whether contact head is coupled with magnet when the door is open, or when the door is closed).

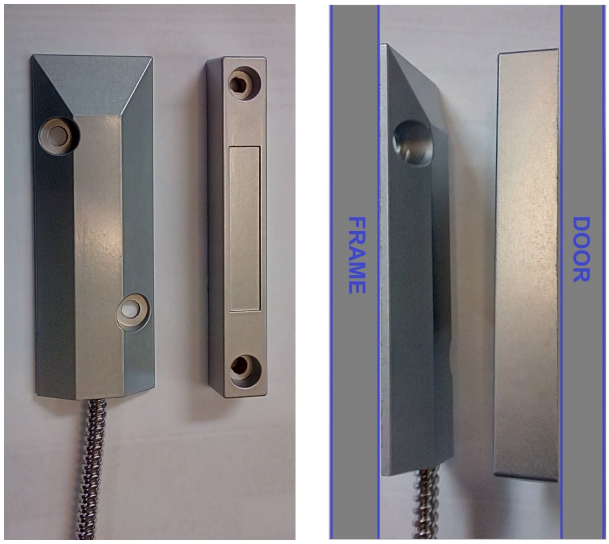


Figure 16: Using of position sensor for door monitoring

5 Troubleshooting

5.1 Possible causes of module failures

If during operation of NB-SI2 module some anomaly, malfunctions or other troubles are recognized, the possible causes of the failures can be classified by following categories:

5.1.1 Power supplying failures

The module is supplied by electrical power from the long-life internal battery. Approximate battery life is specified in paragraph 1.3 „Hardware features”. Battery life can be negatively influenced by circumstances that are described in detail in paragraph 4.1.2 „Risk of premature battery discharge”.

Low battery power becomes evident as irregular drop-outs of signal reception from the module, finally the radio connection with the module completely fails.

Battery is soldered into the printed circuit board of the module and the module has to be disassembled for its replacement. Battery replacement can be performed only by qualified and experienced person. Soldering of battery by unskilled person can cause irretrievable damage of the module. There are only top-quality batteries used in the wacoSystem modules, that have been carefully selected and properly tested. In case of battery replacement by user the new battery parameters should meet same technical requirements (type, capacity, voltage, current load,

auto-discharging current...) as the original battery. It is strongly recommended to use for replacement same type of battery as used in production.

5.1.2 System failures

As „system failure" are considered mainly failures of module's processor, memory, internal supplying or any other failures that cause a complete breakdown of the device. If module's battery voltage is correct, with no signs of discharging and the device still does not communicate through its configuration port and does not respond to any commands and this status will not change even after module's restart (by switching off and switching on its battery), the system failure probably occur. Perform the replacement of the module according to the instructions in paragraph 4.7 and check functionality of the new module. If the new device works properly, label the original module as „defective" and fill in the appropriate documentation prescribed by internal rules for this case.

5.1.3 Transmitter and receiver failures

Transmitting functionality is signaled by flashing of yellow LED on the module printed circuit board. It can be seen through the module transparent casing. Before transmission of the message the module connects to the NB-IoT network, that is signaled by blinking of that LED.

If the module is powered by correct voltage, the module communicates through the configuration port, responds to the configuration commands but the radio-messages from the module are still not received steadily, the possible reason of the trouble can be a failure of transmitting or receiving of radio signal. The typical indication of transmitting or receiving failures is state of „partial" functionality with frequent breakdowns in the receiving data from the module.

All above described troubles could have on common ground, which is unreliability of radio-communication caused by one of these reasons:

- weak radio-signal of NB-IoT network in installation site. RF signal availability can be influenced by weather conditions (rain, fog..), or by some changes around module installation site as well as around NB-IoT provider base station.
- permanent or occasional shading of radio signal caused by construction works or any construction changes within the premises, or by operation around the installation site (moving of machines, cars, etc.);
- permanent, periodical or occasional interference (jamming) of radio signal from external source (another radio system in the same frequency band, or industrial disturbance);
- low level of transmitting signal caused by transmitter failure;
- low level of receiving signal caused by receiver failure;
- low level of transmitting and receiving signal caused by damage of antenna or antenna cable (if external antenna used).

If above described indications of unreliable radio-communication become evident, proceed with troubleshooting of the malfunctioning in following steps:

- visually check surrounding of the installation site to find out if there are any changes that can influence radio signal (e.g. new objects, things, machines...). If there are such negative circumstances, solve the trouble by reorganization of the object or by relocation of the module or its antenna (if external antenna used);
- visually check an external antenna and antenna cable (if used), possibly replace these elements for the spare ones with proven functionality;
- check correctness of module settings and perform the check of module overall functionality as described in paragraph 4.9;
- replace the module according to the paragraph 4.7 and perform the setting and check of overall functionality of the new module as described in paragraph 4.9 after that;
- if the module is not properly working even after its replacement for proven device and equipment, the trouble can be caused by weak signal of NB-IoT network or interference (jamming) from external source in the installation site. In this case consult actual status of coverage and its future development with your NB-IoT network provider.

5.1.4 Failures of communication with meters

Failures of pulse signal transfer from the consumption meters to the correspond module inputs typically appear as „zero consumption" of the meter even though the consumption of the meter is evident, or generally, meter status from remote reading is different than meter status shown in meter's mechanical counter. In this case try to proceed with troubleshooting of the connection with meters in following steps:

- Visually check the meter and connecting cable between meter and radio-module, especially whether the meter's pulse generator is correctly mounted on the meter (if it is removable) and whether the meter or cable are not damaged;
- in case of any doubt check the functionality of cable connection by ohm-meter. If there is a problem with reliability of the connection, or the cable is evidently damaged, replace the cable immediately;
- check whether the cable is correctly associated with the module input (correct port number, correctness of polarity - if required by meter producer);
- Visually check if there are not placed any objects or devices radiating a magnetic field (for example a device for water treatment with magnet, electrical installation...) around the consumption meter. Pulse generators of some types of the consumption meters are very sensitive to the magnetic field presence. If such devise is detected, it must be removed or there must be taken necessary measures to eliminate the magnetic field influence on the pulse generator of the consumption meter. To find more about the influence of the magnetic field on a particular consumption meter, you must follow its manufacturer instructions;
- if there is some possibility of measuring metering pulses, make sure that the meter generates the pulses properly and that these pulses lead up entirely to the radio module input;
- correctness of generating and transfer of metering pulses can be alternatively checked by short-circuiting of the cable on the meter side. If after each short-circuit the status value of the module's counter goes up, the module and cable are probably correct, and the trouble is probable caused by meter or by its pulse generator;
- if the module doesn't read the data even the metering pulses are provably brought to the correct radio module input, check the pulse counter parameter settings (counter mode, trigger edge) according to the paragraph 3.1.5 „Internal Counter Setting Commands". In case the setting is correct, the problem is the most probably in the malfunction of the radio module. Replace the module following the instructions in the paragraph 4.7.

If the module register „false" pulses (consumption registered by remote reading is significantly higher than consumption registered by mechanical counter) and setting of the counter to „slow" mode has not solved the problem, the failure could be caused either by too long or poor-quality cable or strong local disturbance (or combining of these two circumstances). In this case replace the cable for high-quality shielded one or make changes in the installation to shorten the cable.

In case of unstable data transfer from connected sensors the signs of failure are very similar to the troubles with pulse meters - the wrong indication of measured data from sensors. Troubleshooting of this failure is similar with troubleshooting of pulse meters:

- visually check the sensor and connecting cable between sensor and radio-module for any damage;
- check whether the cable is correctly associated with the module input (correct port number, correctness of polarity - if required by sensor producer);
- visually check if there are not placed any objects or devices around the sensor that can influence its functioning;
- check correctness of the sensor input by short-circuiting of the cable on the sensor side. If after each short-circuit the value of the module's counter changes, the module and cable are probably correct, and the trouble is with high probability caused by sensor;
- if the module doesn't register the changes of sensor status even though the changes are provably brought to the correct radio module input, check the counter parameter settings (counter mode, trigger edge) according to the paragraph 3.1.5 „Command for setting of internal counters". In case the setting is correct, the problem is the most probably in the malfunction of the radio module. Replace the module following the instructions in the paragraph 4.7.

5.2 Troubleshooting procedure

To identify a reason of device failure or any anomaly in its operation follow this procedure:

1. No data are available from the NB-SI2 module. In this case it is recommended to check functionality of the module subsystems in following order:
   - check correctness of setting of the module in the central system database;
   - check functionality of power supplying as described in the paragraph 5.1.1 „Power supplying failures";
   - check functionality of the system as described in the paragraph 5.1.2 „System failures";
   - check functionality of transmitting and receiving of the radio-signal as described in the paragraph 5.1.3 „Transmitter and receiver failures".
   - check functionality of receiving pulse signals on the module's input as described in paragraph 5.1.4 „Failures of communication with meters".

2. Readings from some connected meters/sensors are available, but data from some meters/sensors are missing. In this case it is recommended to check functionality of the module subsystems in following order:
   - check functionality of meter/sensor itself;
   - check correctness of central application configuration related to the meter/sensor, especially correctness of its identification and association of the meter/sensor with right port of reading module;
   - check functionality of receiving pulse signals on the module's input as described in paragraph 5.1.4 „Failures of communication with meters".
3. Readings from some connected meter/sensor are incorrect. Check functionality of the module subsystems in following order:
   - check functionality of receiving pulse signals on the module's input as described in paragraph 5.1.4 „Failures of communication with meters";
   - check correctness of pulse detection parameters and setting of counter initial value, multiplier and divisor.
4. Data from the module are coming irregularly, with periodical breakdowns. In this case it is recommended to check functionality of the module subsystems in following order:
   - check functionality of transmitting and receiving of the radio-signal as described in the paragraph 5.1.3 „Transmitter and receiver failures";
   - check functionality of internal battery as described in the paragraph 5.1.1 „Power supplying failures".

NOTE: NB-SI2 module is a reliable device with relatively simple and resilient construction, so that any possible failure of the device is very likely caused by external circumstances, especially mechanical damage, excessive humidity, discharging of internal battery, or voltage pulses induced to the input cables. After each replacement of the module caused by its failure it is recommended to check the root cause of the failure and take necessary measures to eliminate any persisting troubles.

6 Additional information

This manual is focused on description, parameters and configuration options of NB-SI2 RF-modules, designed for operation in NB-IoT network, that are a part of the Softlink's **wacoSystem** product family. More information about all modules of "NB" series (NB-IoT), as well as about WS868 (Sigfox), WM868 (WACO), or WB169 (Wireless M-BUS) series of modules can be found on the manufacturer website:

www.wacosystem.com
www.softlink.cz

If interested in any additional information related to application of radio modules of NB, WS868, WM868, WB169 series or other manufacturer's equipment for telemetry and remote reading of consumption meters, feel free to contact manufacturer:

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