

# Connection Manual NBS Family

Description

## 1 History

Version	Date	Changes	Status
Draft		First draft	In progress

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## 5 About this Document

This document describes the firmware functions of the NBS family. A basic knowledge of

- NB-IoT
- TCP/IP Networks
- MQTT
- JSON

is required.

### 5.1 Definition of Symbols

	The attention symbol refers to actions, which can cause damage to material or equipment.
	The notice indicates necessary conditions for error-free operation. It picks out important details, makes the job easier, and gives tips and advice on the optimal use of hardware and software.

## 6 Introduction

The NBS family is a battery driven Narrowband IoT ("NB-IoT") sensor with multiple different sensor elements. Following table shows an overview of the supported sensors.

**Table 1 - Overview of the available sensors**

Feature/Sensor	NBS-121	NBS-140	NBS-180
Air Pressure	Yes	Optional	Yes
CO2	No	No	Optional
TVOC	No	No	Yes
Temperature	Yes	Yes	Yes
Humidity	Yes	Yes	Yes
Contact	No	Yes	No
Pulse Counter	No	Yes	No
Leakage	No	Yes	No
Battery Voltage	Yes	Yes	Yes



## 7 MQTT

The NBS uses MQTT(S) for the communication. There are two topics responsible for the interaction with the device - one for listening for commands and settings #1 and one for publishing data #2.

The application which wants to communicate with the NBS has to subscribe the NBS publishing topic#2 and publish the commands and setting to the subscription topic #1.

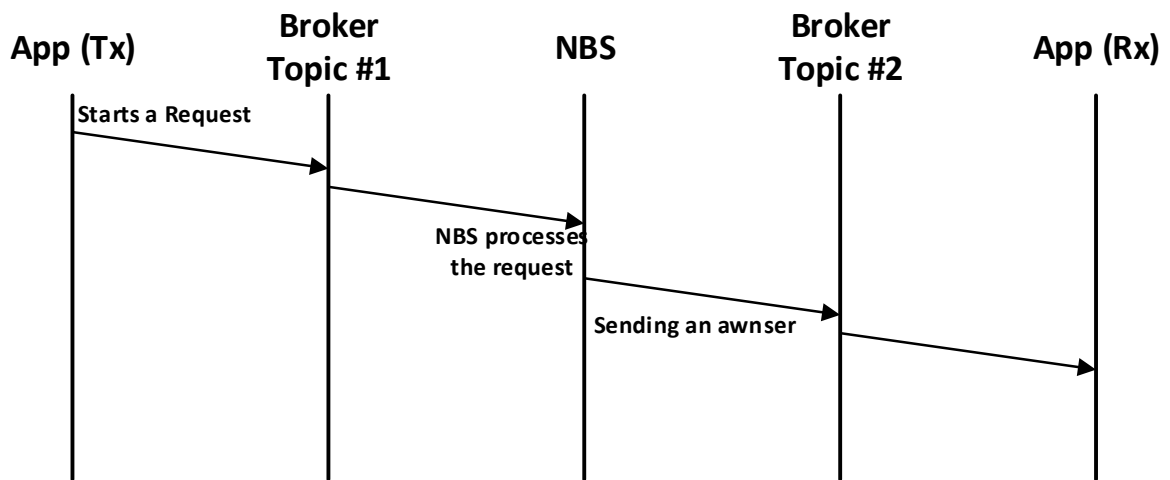


Figure 1 - MQTT Communication via 2 Topics

## 8 Data Format

The payload from the MQTT is encoded in a JSON string.

### 8.1 JSON Data Format

The data is an array of objects with key value pairs.

```
[ { ... }, { ... }, ... ]
```

The values are identified by an id which is similar to the OMA IPSO LWM2M object id. All objects are described in more detail in the next chapter.

The objects inside this array represent a value identified by key-values pair. These keys are defined:

Key	Description
<b>e</b>	Execute (for e.g. starting a firmware update or initiating a reset)
<b>n</b>	Name (ID) of the value
<b>g</b>	Get a setting
<b>s</b>	Set a value
<b>v</b>	Value (can be a scalar or an array)

#### Examples

```
[{ "n": "/3303/0/5700", "v":23.5 }]  
[{"n": "/3303/0/5700", "v": [23.5, 25.1] }]  
[{"n": "/3/0/4" }]
```



Please avoid to use formatting strings like <cr>, <lf> or white spaces.

## 9 Attributes and Telemetric Values

All IDs in the range 26xxx are private IPSO Objects (for reusing by companies).

These shortcuts are used in the following tables.

Shortcut	Description
<b>B</b>	Cannot be read directly, only by value bundle requests
<b>E</b>	Execution command
<b>Int</b>	Integer
<b>R</b>	Read only
<b>RW</b>	Read and write
<b>S</b>	These values cannot be read but are send by the NBS or Server

Following tables give an overview of all possible parameters and values of the NBS devices.

### 9.1 Attributes

#### 9.1.1 General properties

ID	Type	Description
<b>/3/0/0</b>	String/B	Manufacturer
<b>/3/0/2</b>	String/B	Serial
<b>/3/0/3</b>	String/B	Firmware Version (NBS)
<b>/3/0/4</b>	E	Execute Reboot
<b>/3/0/5</b>	E	Factory Reset
<b>/3/0/17</b>	String/B	Device Type (e.g. "NBS-121")
<b>/26400/0/2</b>	Int/RW	STV
<b>/26400/0/3</b>	Int/RW	MSI [s]
<b>/26400/0/4</b>	Int/S	Message Type, sending reason: 0: Register Message (Cold start/Reset) 1: Measurement Values 2: Threshold Violation 3: Acknowledge of settings/commands 4: Not Acknowledge of settings/commands
<b>/26400/0/10</b>	Int/RW	Backchannel Interval (BCI)Number after how many MSI the module keeps online
<b>/26400/0/11</b>	Int/S	KOT – Keep online time: Time in [s] how long the NBS keeps online after last received message
<b>/26410/0/1</b>	E	Request for LTE Quality Bundle
<b>/26410/0/2</b>	E	Request for HW Information Bundle
<b>/26410/0/3</b>	E	Request for FW Information Bundle
<b>/26410/0/4</b>	E	Request for Threshold Bundle

### 9.1.2 Thresholds

ID	Type	Description
/26505/3303/0	Float/RW	Lower Temperature Threshold [°C]
/26505/3303/1	Float/RW	Upper Temperature Threshold [°C]
/26505/3304/0	Float/RW	Lower Humidity Threshold [%]
/26505/3304/1	Float/RW	Upper Humidity Threshold [%]
/26505/3315/0	Float/RW	Lower Air Pressure Threshold [hPa]
/26505/3315/1	Float/RW	Upper Air Pressure Threshold [hPa]
/26505/3325/0	Float/RW	Lower TVOC Threshold [ppm]
/26505/3325/1	Float/RW	Upper TVOC Threshold [ppm]
/26505/3325/4	Float/RW	Lower CO2Threshold [ppm]
/26505/3325/5	Float/RW	Upper CO2Threshold [ppm]

### 9.1.3 Radio Module

ID	Type	Description
/26515/0/1	String/B	Model
/26515/0/2	String/B	Firmware Version
/26515/0/3	String/B	IMEI
/26515/0/4	String/B	IMSI
/26515/0/10	String/RW	APN (Access Point Name)
/26515/0/11	String/RW	APN User
/26515/0/12	String/RW	APN Password
/26515/0/20	String/RW	Used Bands

### 9.1.4 MQTT

ID	Type	Description
/26520/0/1	String/RW	Broker Address
/26520/0/2	Int/RW	Broker Port
/26520/0/3	Int/RW	Encryption Enable
/26520/0/4	String/RW	Client ID
/26520/0/5	String/RW	Receive Topic
/26520/0/6	String/RW	Send Topic
/26520/0/7	String/RW	Username
/26520/0/8	String/RW	Password

### 9.1.5 Message Bundle Requests

ID	Type	Description
/26530/0/1	E	LTE quality information
/26530/0/2	E	HW Information
/26530/0/3	E	FW Information
/26530/0/4	E	Threshold Bundle

### 9.1.6 Firmware Update / File Transfer

ID	Type	Description
/5/0/1	String/R	NBS firmware filename
/5/0/2	E	Execute NBS update
/26525/0/1	String/RW	Radio DFOTA firmware URI
/26525/0/2	E	Execute radio update
/26525/0/10	String/S	Download request with filename
/26525/0/11	Int/S	Requested Block size
/26525/0/12	Int/S	Number of requested block Request
/26525/0/15	Ins/S	Control commands for file transfer 1: abort file transfer 2: download done
/26525/0/20	String/S	Data base64 encoded
/26525/0/21	Int/S	CRC8

## 9.2 Telemetric Values

### 9.2.1 Sensors

ID	Type	Description
/3/0/7	Int/R	Battery Voltage [mV]
/3200/0/5500	Int/R	CONTACT
/3200/0/5501	Int/R	Pulse Counter
/3200/1/5500	Int/R	Leakage
/3303/0/5700	Float/R	Temperature [°C]
/3304/0/5700	Float/R	Humidity [%]
/3315/0/5700	Float/R	Air Pressure [hPa]
/3325/0/5700	Float/R	CO2 [ppm]TVOC [ppm]
/3325/1/5700	Float/R	TVOC [ppm]
/3333/0/5506	Int/R	Timestamp (Unix time) [s]

### 9.2.2 NB-IoT

ID	Type	Description
/26500/0/1	Int/R	RSRQ
/26500/0/2	Int/R	RSRP
/26500/0/3	Int/R	RSSI
/26500/0/4	Int/R	SNR
/26500/0/5	Int/R	Last NW Reject Error Code

## 9.3 Maximum Ratings

These are the maximum Ratings for the configurable settings.

### 9.3.1 Integer Values

ID	Name	Min	Max
/26400/0/1	STV	0	4
/26400/0/2	MSI	30	65535
/26400/0/10	BCI	1	65535
/26520/0/2	MQTT Server Port	1	65535
/26520/0/3	MQTT Encryption Enable	0	1

### 9.3.2 Floats

ID	Name	Unit	Format	Min	Max
/26505/3303/*	Temperature	°C	(-)xx.x	-40.0	85.0
/26505/3304/*	Humidity	%	xx.x	0.0	100.0
/26505/3315/*	Air Pressure	hPa	xxxx.x	300.0	1200.0
/26505/3325/*	TVOC	ppm	xxxx.xx	0.00	1000.00
/26505/3325/*	CO2	ppm	xxxx.x	400	5000

### 9.3.3 Strings

ID	Name	Max Length [Bytes]
/5/0/1	NBS Firmware File Name	20
/26515/0/10	APN URL	80
/26515/0/11	APN User	20
/26515/0/12	APN Password	20
/26515/0/20	Used Bands	80 (see also chap. 9.4.1)
/26520/0/1	MQTT Broker Address	80
/26520/0/4	MQTT Client ID	20
/26520/0/5	MQTT Receive Topic	80
/26520/0/6	MQTT Send Topic	80
/26520/0/7	Username	20
/26520/0/8	Password	200
/26525/0/1	Radio DFOTA Firmware URI	200

## 9.4 Special Formats

### 9.4.1 LTE Bands

The active LTE bands are defined by a string. This string has the following format:

`N, B1, B2, ..., BN`

N: Number of enabled bands

Bx: Band number to search for a network

For example: To search on three bands for a network, e.g. 3, 8 and 20, the string looks like:

`3, 3, 8, 20`



## 10 Message Type Description

### 10.1 Registration Message

After a cold start or reset, the device sends a registration string to the server.

This RM contains:

- Serial number
- Device type (NBS-121 or NBS-140)
- Transfer reason (0)
- KOT – Keep online Time

If the device receives no acknowledge, it tries to reach the server again at longer and longer intervals to reduce high power consumption. These intervals are [min]:

- 1
- 5
- 15
- 60
- 360
- 1440 (keeps until the server answers)

### 10.2 Measurement Data Message

The NBS has a measurement interval (MSI) and a number of values to store (STV). A measurement is performed on each MSI and the value is stored. After the number of stored values reaches STV or a threshold violation occurs the values are send to the server.

The Measurement Data Message contains:

- timestamp of the **last** measurement
- all stored measurement values
- RSRP value
- Transfer reason (1 or 2)

If the measurement values contain an array of data, then the **first** element is the **oldest** one. The time, when the value is taken can be calculated from the MSI and the timestamp of the last value.

### 10.3 Configuration and Execution Command

This CEC contains a configuration or execution request. There must be only one request at a time. The server must wait for a acknowledge message. If the acknowledge does not arrive within 15s the server may resend the request.

## 10.4 Data Transfer Message

The DTM contains the firmware for the NBS. The update process is described in chapter 13.4.1.

## 10.5 Value Bundles

To reduce the amount of packages, which are sent the broker can request a bundle of values. This bundle contains a predefined set of information. These bundles are:

- LTE quality information
  - RSRQ
  - RSRP
  - RSSI
  - SNR
  - Last NW Reject Error Code
- HW Information
  - Serial Number
  - Device Type
  - IMEI
  - IMSI
- FW Information
  - FW-Version NBS
  - FW-Version Radio Module
- Threshold Bundle
  - All Thresholds (/26505/\*)

## 11 Cold start / Reset Procedure

After a cold start the device performs the first measurement and it tries to register the NB-IoT network and connect to the MQTT broker with the "Registration Message – RM". If the connection is established the device remains on-air in order to receive new configuration or commands. This timer resets on every command/setting is received by the NBS.

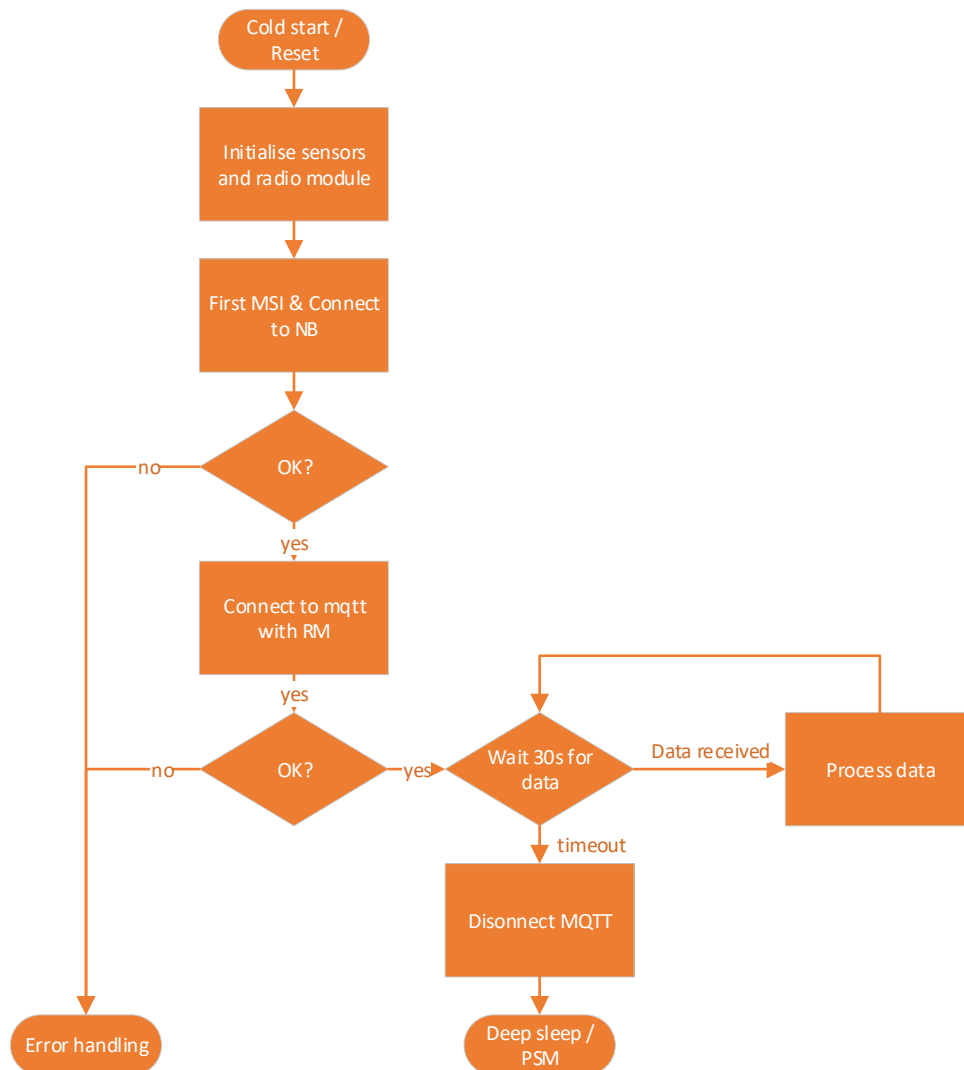


Figure 2 - Cold start procedure

### 11.1 Message Example

```
[  
{ "n": "/3/0/2", "v": "NBS121012345"},  
{ "n": "/3/0/17", "v": "NBS-121"},  
{ "n": "/26400/0/3", "v": 0},  
{ "n": "/26400/0/11", "v": 30}  
]
```

## 12 Measurement Interval

The measurement interval MSI is the main time interval for the sensor. After a MSI the NBS collects the value from all sensors and checks if it must send the values to the MQTT broker. The data have to be send if

- STV is reached
- A threshold violation is occurred
- BCI is reached

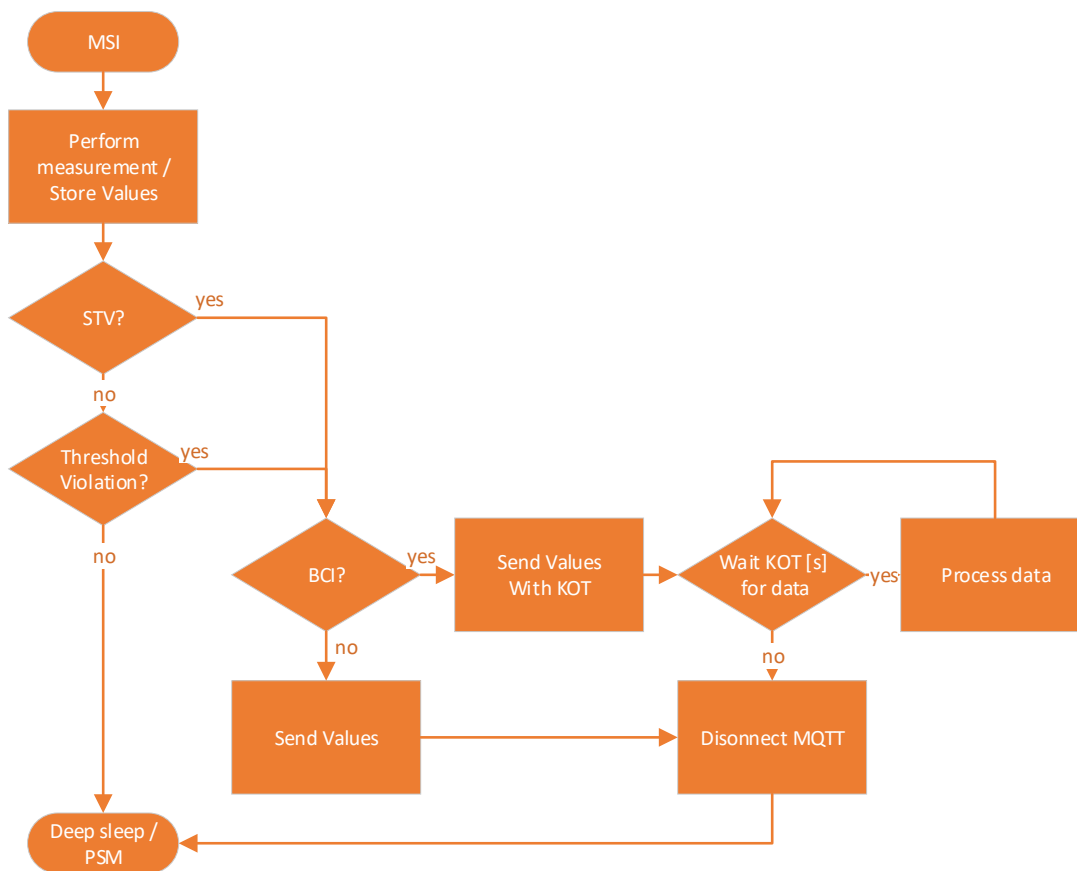


Figure 3 - MSI

### 12.1 STV – Store Values

On each MSI the value of each sensor is stored in the memory. The STV is the maximum amount of values which are stored before they are sent to the broker.

### 12.2 BCI – Back Channel Interval

If the numbers of performed MSI reaches the BCI, the stored values are sent and the NBS remains on-air for 30s. If within this period a configuration/execution request arrives, it will be processed and the online timer is set to 30s again (timeout).



The BCI sends all stored values and resets the STV.

## 12.3 Message Example

### 12.3.1 STV

```
[  
{"n":"/3333/0/5506", "v":1592825443},  
{"n":"/3303/0/5700", "v":[23.5,23.3,23.2,23.4]},  
{"n":"/3304/0/5700", "v":[45.1,44.0,46.1,45.9]},  
{"n":"/26400/0/3", "v":1}  
]
```

### 12.3.2 Threshold Violation


```
[  
{"n":"/3333/0/5506", "v":1592825443},  
{"n":"/3303/0/5700", "v":[23.5,27.3]},  
{"n":"/3304/0/5700", "v":[45.1,44.0]},  
{"n":"/26400/0/3", "v":2}  
]
```


### 12.3.3 BCI with KOT

```
[  
{"n":"/3333/0/5506", "v":1592825443},  
{"n":"/3303/0/5700", "v":[23.5,27.3]},  
{"n":"/3304/0/5700", "v":[45.1,44.0]},  
{"n":"/26400/0/3", "v":1},  
{"n":"/26400/0/11", "v":30}  
]
```

## 13 Commands and Settings via Back Channel

If the JSON packet contains the KOT parameter (/26400/0/11), the device remains online for the value of the KOT [s]. If the NBS receives a message the timer will be reset to the KOT.

	The NBS can only handle <b>one request</b> at time. The server <b>must</b> wait for the answer message.
---	---

	The maximum message size (MQTT payload) is <b>250 Bytes</b>
---	---

### 13.1 Configuration

The Broker addresses the configuration with the "s" key followed by the name of the setting and set the new value with the "v" key.

#### Positive example

Setting a new value for the upper temperature threshold. Request for the current setting (optional if known):

```
[{"g": "/26505/3303/1"}]
```

Answer with the current setting:

```
[{"n": "/26505/3303/1", "v": 20.1}]
```

New setting request:

```
[{"s": "/26505/3303/1", "v": 25.0}]
```

The NBS tries to set the value and answer with the new value if it could be set or the old value if something goes wrong:

```
[{"n": "/26505/3303/1", "v": 25.0}]
```

#### Negative example

In case of an error. E.g., requesting a temperature threshold out of range:

```
[{"s": "/26505/3303/1", "v": 90.0}]
```

Answer: with the old value:

```
[{"n": "/26505/3303/1", "v": 25.0}]
```

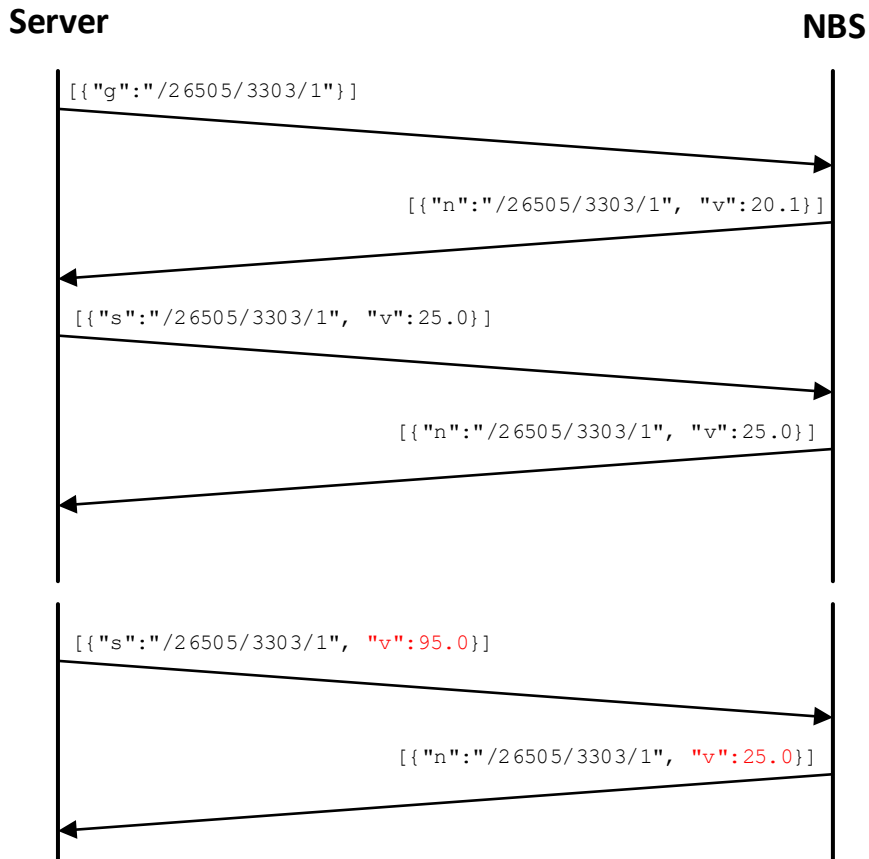


Figure 4 - Set a new value

## 13.2 Execute a Command

The broker addresses the execution command with the "e" key followed by the name, e.g. the command to reset the device:

```
[{"e":"/3/0/4"}]
```

The NBS answers with the same message and then it resets.

### 13.3 Bundle Request

Some settings can only be received in a bundle. The server ask for a bundle, e.g. the "HW Information" bundle:


```
[{"e":"/26410/0/2"}]
```

The NBS answer with the requested bundle:

```
[
{"n":"/3/0/2", "v":"NBS121012345"},
{"n":"/3/0/17", "v":"NBS-121"},
{"n":"/26515/0/1", "v":"Quectel_BC66"},
{"n":"/26410/0/3", "v":"867997030574247"},
{"n":"/26410/0/4", "v":"901405101097035"}
]
```

### 13.4 FOTA

The firmware from the NBS and the radio module can be updated over the air.

	<p>Do not power off or reset the device while an update process is running!</p>
---	---

#### 13.4.1 NBS

The NBS firmware can be updated over the air. The firmware file can be transferred via JSON/MQTT.

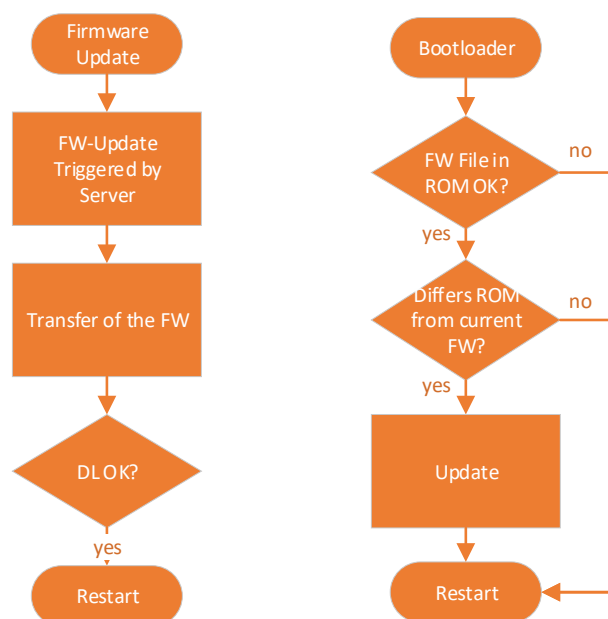


Figure 5 - FW Update



#### ***13.4.1.1 File Transfer Procedure***

The file transfer is triggered by the "execute firmware update" command. After the NBS received the start command, it asks for the first block of the firmware file. The CRC of the received data block is checked. If it is OK the NBS stores the data and requests the next block, if not it will ask for this block again. If the payload in "/26525/0/20" smaller than the block size or equal zero, then it is the last packet and the NBS sends a stop.

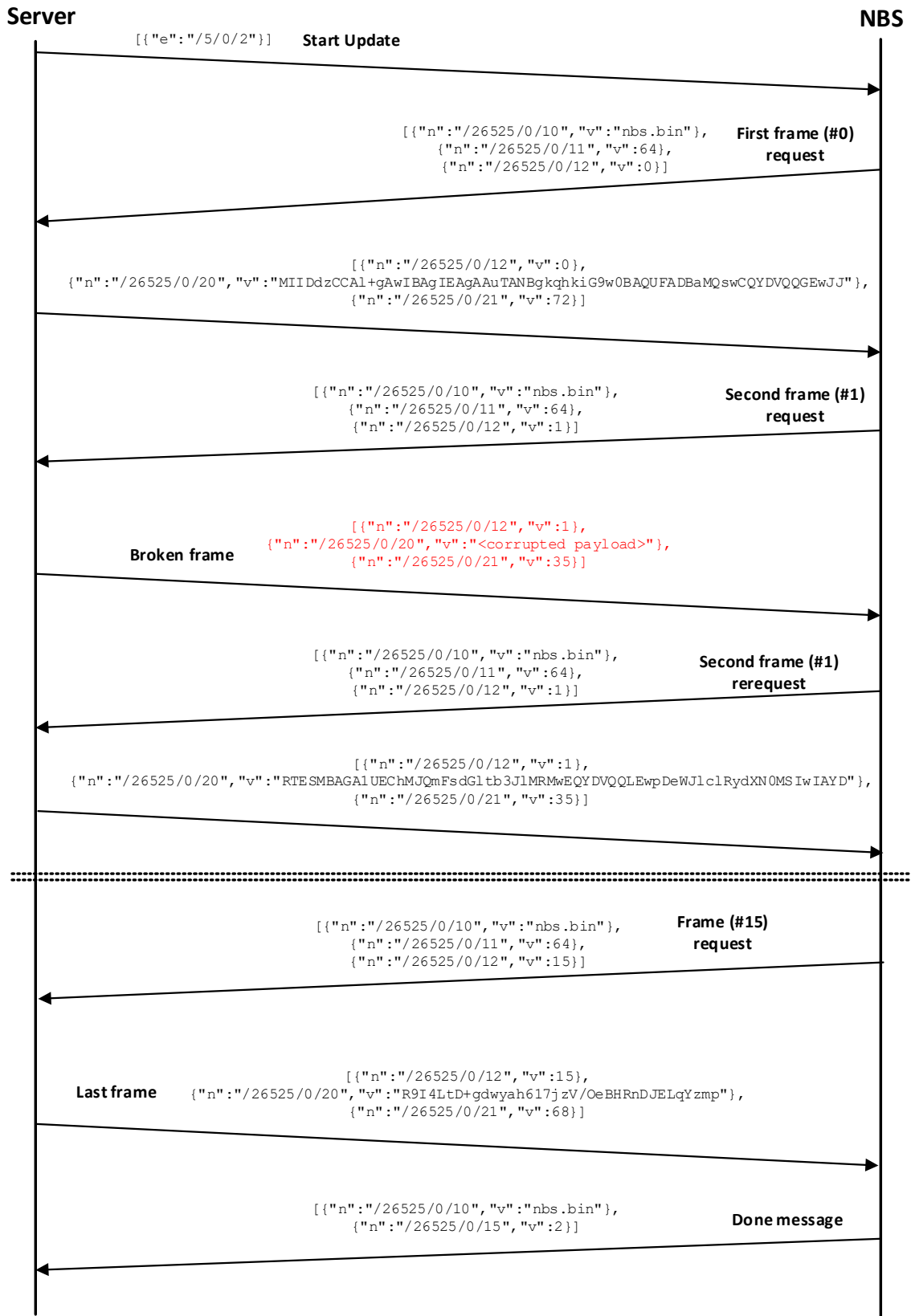


Figure 6 - File Transfer Procedure

### 13.4.1.2 CRC8 Algorithm

```
uint8_t crc8(uint8_t *data, uint8_t len){  
  
    uint8_t crc = 0xff; /* initialization */  
    const uint8_t poly = 0x31; /* polynomial*/  
  
    uint8_t i, j;  
  
    for (i = 0; i < len; i++) {  
  
        crc ^= data[i];  
  
        for (j = 0; j < 8; j++) {  
  
            if ((crc & 0x80) != 0) {  
  
                crc = (uint8_t)((crc << 1) ^ poly);  
  
            } else {  
                crc <<= 1;  
            }  
        }  
  
    }  
  
    crc ^= 0x00;  
  
    return crc;  
}
```

Figure 7 - CRC8 c algorithm

### 13.4.2 Radio Module

The FOTA procedure for the Quectel radio module requires an http(s) server. The URL of the update file can be set with "/26525/0/1". E.g.:

```
[{"s":"/26525/0/1",  
"v":"http://10.64.96.137/bc66/BC66NBR01A07-BC66NBR01A10.bin"}]
```

This message will be acknowledged by

```
[{"n":"/26525/0/1",  
"v":"http://10.64.96.137/bc66/BC66NBR01A07-BC66NBR01A10.bin"}]
```

To start the update process execute "/26525/0/2":

```
[{"e":"/26525/0/2"}]
```

The device acknowledge this by sending the command back to the server. The NBS disconnect from server starts the update.

After the update the NBS sends the current firmware version of the radio module, e.g.:

```
[{"n":"/26515/0/2", "v":"BC66NBR01A10"}]
```

## 14 LED Blink Code Description

Start Code	Sub Code	Module	Description
1 x GN	-/-	All	Data successfully sent
1 x BL		Main	
1 x BL	2 x GN	Main	System starts
1 x BL	3 x GN	Main	Application starts
2 x BL	2 x GN	Radio	Waiting for IP
2 x BL	2 x RD	Radio	Error in communication to the module

The blue LED indicates the module and the following red or green the code.

## 15 Initial start-up / Factory Defaults

The NBS gets its initial settings while the production. Some of these values are provided by the customer and are used to connect to a NB-IoT network and the MQTT broker. These values are also used for a factory reset.

These settings are:

- NB-IoT
  - APN
    - URL
    - User
    - Password
  - Bands
- MQTT
  - Host address
  - Port
  - User
  - Password
  - Encryption enable

## 16 List of abbreviations

Abbreviation	Meaning
<b>BCI</b>	Backchannel Interval
<b>CEC</b>	Configuration and Execution Command
<b>FOTA</b>	Firmware update over the air
<b>KOT</b>	Keep online time
<b>JSON</b>	JavaScript object notification
<b>MSI</b>	Measurement Interval
<b>MDM</b>	Measurement Data Message
<b>RM</b>	Registration Message
<b>STV</b>	Numbers of stored values before sending them to the server