Wireless Sensor Network for Measuring Soil Moisture

SoilNet CPA

(Version LoRa, NB-IoT)

Description and Operation

- Version 5.0 -

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Subject to technical modifications.

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1   Introduction

SoilNet CPA (**C**ontrol **P**anel **A**pplication) is a software to receive, decode, answer, visualize and export the data packets from the wireless sensor network SoilNet V5.

The SoilNet soil moisture network supports both LoRa (Long Range) and the NB-IoT (Narrowband Internet of Things) Low Power Wide Area Network (LPWAN) radio technology standards. In both versions, the data output to and from the CPA is transmitted via a VPN tunnel. Depending on the LPWAN version (NB-IoT or LoRa), this is done using different protocols (UDP protocol for NB-IoT and MQTT protocol for LoRa)

The CPA uses configuration files to specify how the network data is processed and to describe the incoming and outgoing data. Furthermore, the operation parameters such as the measuring interval can be specified. The time synchronization of the measuring units is carried out using a time stamp in the return package (CPA -> sensor unit).

Furthermore, different measuring units can be defined (e.g. soil moisture station, weather station, groundwater level station, etc.), which can be operated in parallel.

For each sensor unit there is a separate tabular representation of the data on a website. Here, the most recently received data can be viewed and the proper operation of the sensors can be checked.

The SoilNet CPA application is running on a Linux based system, e.g. Ubuntu or Raspberry Pi OS.

2   Installation

2.1   Hardware requirement

- Linux based hardware (Ubuntu X86)
- 1(v)CPU
- Min. 2 Gb RAM
- Min. 20 Gb SSD
- Min. 20 TB Traffic

Or

CX11 Virtual Machine Cloud System HETZNER (Ubuntu X86)

Or

Raspberry Pi 4 (Raspberry Pi OS)

- 4 Gb RAM
- 16 Gb SD Card

2.2   Software requirements

- Ubuntu 18.04 or higher
- OpenVPN client software
- soilnetcpa_0.3.11_amd64.deb or soilnetloracpa_0.3.11_arm.deb
- nginx

2.3   Step by Step

Install software

- ```
  $ sudo apt install openvpn nginx unattended-upgrades
  ```
  Copy the current version and install it:
- ```
  sudo dpkg -i soilnetcpa_0.3.11_amd64.deb
  ```
  Copy the example config:
- ```
  $ sudo cp /etc/soilnetloracpa/soilnetloracpa.conf.example
  /etc/soilnetloracpa/soilnetloracpa.conf
  ```

Edit soilnetcpa config:

```
sudo nano /etc/soilnetloracpa/soilnetloracpa.conf

# PostgreSQL is not used in newer versions.
POSTGRES_DSN="postgres://loracpa:gjgjeaioklrjh4390@localhost/lor
acpa"
# set to enable lora
MQTT_SERVER="tcp://localhost:1883"

# path for import configuration
IMPORT_CONFIG="/etc/soilnetloracpa/import-config"

# path for export configuration
EXPORT_CONFIG="/etc/soilnetloracpa/export-config"

# path for view configuration
VIEW_CONFIG="/etc/soilnetloracpa/view-config"

# path for node configuration
NODE_CONFIG="/etc/soilnetloracpa/node-config"

# set to enable NBIoT
NBIOT_CONFIG="/etc/soilnetloracpa/nbiot.xml"

# base path for data
DATA_PATH="/var/lib/soilnetloracpa/"

# path for static web data
WEB_PATH="/etc/soilnetloracpa/html"
```

Copy from

source\soilnetloracpa

to

etc/soilnetloracpa

Folder view-config

Folder node-config

Folder export-config

Folder inport-config

Edit node parameter:

/etc/soilnetloracpa/nbiot.xml

Enable nginx redirect:

```
#sudo nano /etc/nginx/sites-enabled/default
map $http_upgrade $connection_upgrade {
    default upgrade;
    '' close;
}

server {
    listen 80 default_server;
    listen [::]:80 default_server;
    root /var/www/html;

    # Add index.php to the list if you are using PHP
    index index.html index.htm index.nginx-debian.html;

    server_name _;

    location / {
        auth_basic "Enter password (username: soilnet)";
        auth_basic_user_file /etc/nginx/.htpasswd;

        # proxy to soilnetcpa
        proxy_pass http://localhost:8081/;
        proxy_http_version 1.1;
        proxy_set_header Upgrade $http_upgrade;
        proxy_set_header Connection $connection_upgrade;

        proxy_set_header Origin "http://localhost:8081"; # fix blocked
websocket

        proxy_connect_timeout 1h;
        proxy_send_timeout 1h;
        proxy_read_timeout 1h
    }
}
```

Set the password:

```
$ sudo sh -c "echo -n 'soilnet:' >> /etc/nginx/.htpasswd"
$ sudo sh -c "openssl passwd -apr1 >> /etc/nginx/.htpasswd"
```

Restart and enable nginx:

```
$ sudo systemctl restart nginx
$ sudo systemctl enable nginx
```

Set up OpenVPN

Copy the OpenVPN config from 1nce to /etc/openvpn.

The folder should look like this:

```
client
dev tun
proto udp
remote vpn.1nce.net 1194
resolv-retry infinite
nobind
explicit-exit-notify 3
keepalive 1 5
user root
group nogroup
;persist-key
;persist-tun
ns-cert-type server
verb 3
;auth-nocache
auth-user-pass credentials.txt
auth-retry nointeract
<ca>
-----BEGIN CERTIFICATE-----
.....
```

Test OpenVPN (optional)

```
$ sudo openvpn --config client.conf
```

Enable and start OpenVPN

```
$ sudo systemctl enable openvpn@client
$ sudo systemctl start openvpn@client
```

Check OpenVPN status

```
$ sudo systemctl status openvpn@client
```

```
You find more infos about OpenVPN connection at 1NCE.com
```

Start soilnetloracpa application:

```
sudo systemctl start soilnetloracpa
```

Stop soilnetloracpa application:

```
sudo systemctl stop soilnetloracpa
```

Status soilnetloracpa application:

```
sudo systemctl status soilnetloracpa
```

Automatic start after reboot:

```
sudo systemctl enable soilnetloracpa
```

3   Software Workflow

3.1   Datapath NB-IoT

Figure 1: Data path of the SoilNet NB-IoT version

The SoilNet sensor units are connected to a private NB-IoT network operated by a cellular network provider and can be accessed via the Internet Protocol (IP).

For security reasons, the IP network is not directly connected to the Internet. The sensor units therefore do not use public IP addresses for the connection, but only the private addresses from the address spaces defined in (RMK + 96) or (WKD + 12).

The open source software "OpenVPN" is used for this access.

The SoilNet CPA receives and sends IP packets to the sensor boxes via this VPN tunnel and the provider network.

The sensor units transmit the data packets to the "SoilNetCPA" software using the UDP protocol (NB-IoT).

The software can assign the sensor units based on the IP address.

An advantage of this approach is the lower implementation effort in the sensor units and a lower transmission rate of the data, since there is no need to transmit any further data for identification.

3.2   Datapath LoRa

Figure 2: Data path of the SoilNet LoRa version

The sensor units are connected to the LoRa-WAN network via a base station that consists of a LoRa modem (concentrator) and a Linux system (Raspberry Pi).

The "Packet Forwarder" service runs on this computer and transfers incoming packets from the Concentrator to the LoRaWAN stack via UDP.

A software component called "LoRa Gateway Bridge" converted a UDP packet into an MQTT packet for the "Packet Forwarder".

The LoRa stack now processes the data packets further. After decryption, the LoRa App Server sends the packet to the SoilNetCPA using MQTT.

Communication in the other direction is analogous. However, there is a difference that the LoRa Network Server temporarily stores messages for the sensor boxes.

The reason for this is the restriction that the data can only be received from the sensor unit in certain time windows (always a few seconds after they have sent a message).

In a LoRaWAN network, identification is based on the DeviceEUI in the LoRaWAN header.

3.3   Internal program sequence

Figure 3: Internal program sequence

1. The LoRaWan / NB-IoT handler takes over the data package via MQTT (LoRa) / UDP (NB-IoT) from the network.

2. The LoRaWAN / NB-IoT handler sends a response packet to the sensor unit to confirm receipt of the data, set measurement parameters and set the time of the sensor unit for synchronization. The measurements are stored in a FIFO buffer on the sensor units and

are only deleted from this buffer after the confirmation has been received. If the sensor unit has not received a confirmation, it tries to send the same packet again the next time. A complete time series is thus possible.

3. The LoRaWAN / NB-IoT handler decodes the received data packet and forwards it to the data packet handler. The LoRaWAN / NB-IoT handler uses the XML-based import configuration (see section 3.3.1) which specifies the format of the data packet.

4. The data packet handler now forwards the packet to the output unit for data export (.csv). Here the XML-based export configuration serves as a format descriptor (see section 3.3.4).

5. A web socket connection is used to view the most recently received data via a web browser. Another XML-based configuration file describes the output on the website in tabular form (see section 3.3.3).

4   Configuration files

There are different configuration files (format .xml) to determine how the software works:

4.1   Import config file

The import config file describes the format of the incoming data packets. Here it is specified at which position a measured value is located and in which format it is available (decimal, float, timestamp, etc.)

Example name:

/etc/soilnetloracpa/import-config/nbiot_1_import_format.xml

Example content:

```xml
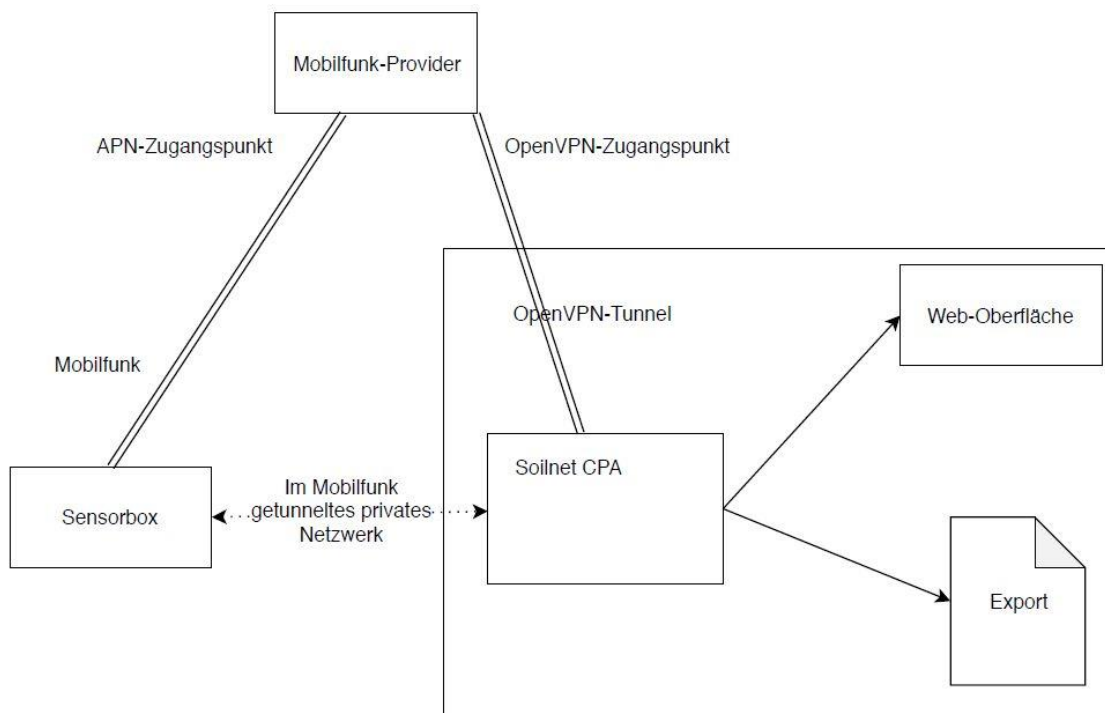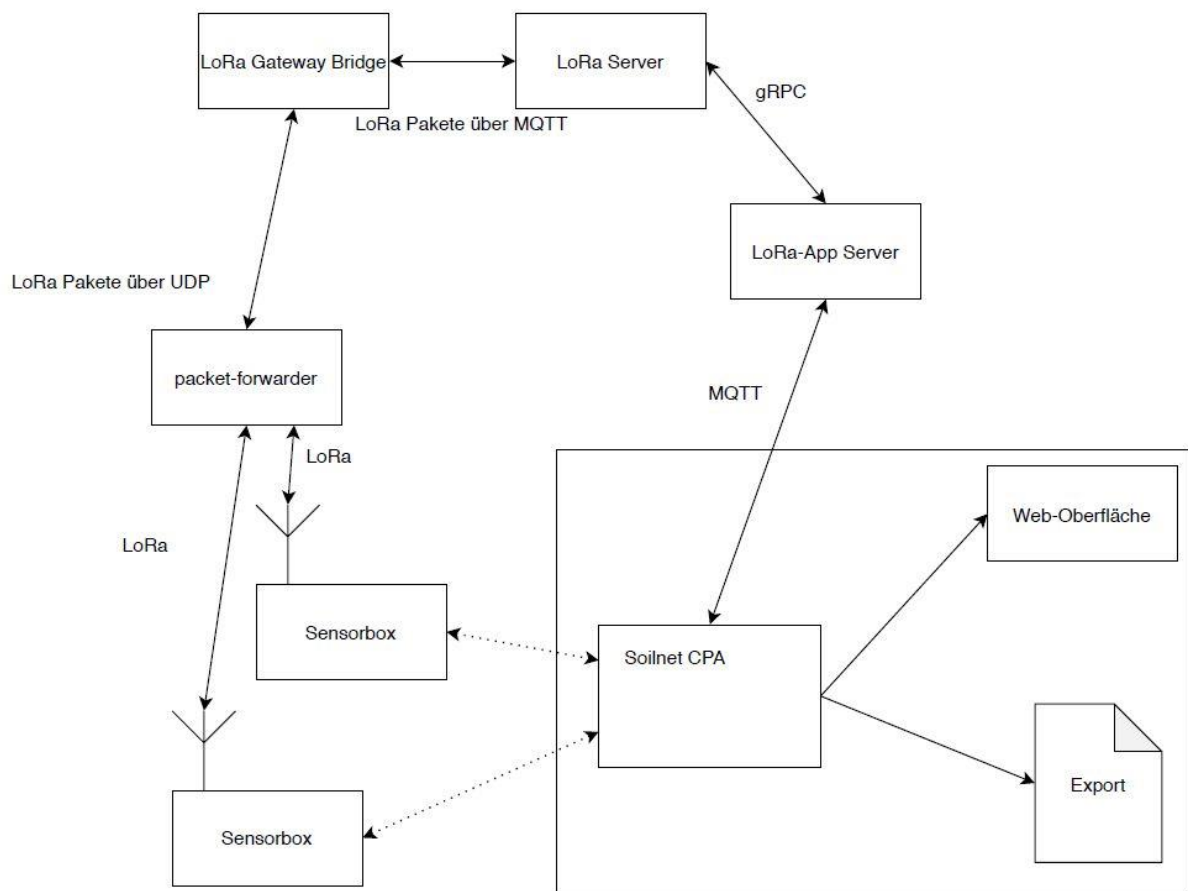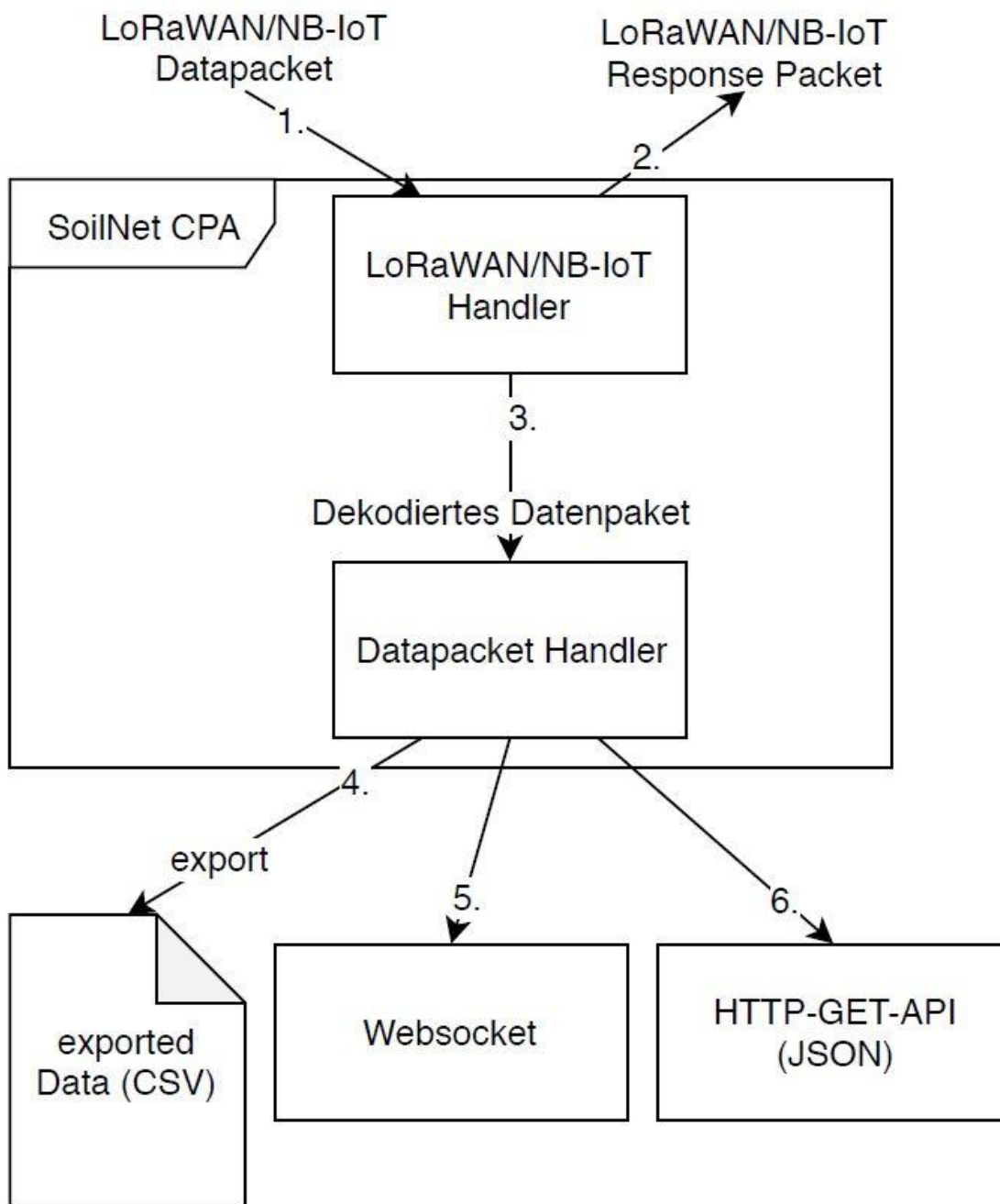<?xml  version="1.0"  encoding="UTF-8"?>
<importformat>
    <name>NBIoT_Cosmic_1_2</name>
    <appEUI>0</appEUI>
    <applicationID>1000</applicationID>
    <version>V1.0.1</version>
    <date>08.04.2020</date>
        <value>
            <name>UTC_timestamp</name>
            <format>%d</format>
            <description>time of the measurement since 1970</description>
        </value>
        <value>
            <name>counter</name>
            <format>%d</format>
            <description>Logger Cycle Counter</description>
        </value>
        <value>
            <name>temperature_int</name>
            <format>%f</format>
            <unit>C</unit>
            <description>temperature, logger sensor, internal</description>
        </value>
        <value>
            <name>pressure_int</name>
            <format>%f</format>
            <unit>hPa</unit>
            <description>pressure, logger sensor, internal</description>
        </value>

        etc.
```

4.2   Node config file

The node configuration file contains information specific to the sensor unit. The name of the unit and the measuring interval are specified here. There is also the option of entering metadata for the table display in the web browser.

Example name:

/etc/soilnetloracpa/node-config/nbiot_1_node.xml

Example content:

```xml
<?xml  version="1.0"  encoding="UTF-8"?>
<nodeconfiguration>
    <appEUI>0</appEUI>
    <node name="ED_AS_01">
        <interval>900</interval>
        <meta name="SOLAR">X</meta>
        <meta name="STATUS">T</meta>
    </node>
    <node name="ED_AS_02">
        <interval>600</interval>
        <meta name="SOLAR"> </meta>
        <meta name="STATUS"> </meta>
    </node>
    <node name="ED_AS_03">
        <interval>900</interval>
        <meta name="SOLAR">X</meta>
        <meta name="STATUS">T</meta>
    </node>
    <node name="ED_AS_04">
        <interval>900</interval>
        <meta name="SOLAR">X</meta>
        <meta name="STATUS">I</meta>
    </node>
    <node name="ED_AS_05">
        <interval>900</interval>
        <meta name="SOLAR">X</meta>
        <meta name="STATUS">I</meta>
    </node>

    etc.
```

4.3 View config files

The view config files describe the format of the table display in the web browser (e.g. definition of the columns and rows).

Example name:

/etc/soilnetloracpa/view-config/nbiot_1_view_format.xml

Example content:

```xml
<?xml  version="1.0"  encoding="UTF-8"?>
<viewformat>
    <name>NBIoT_Soilmoisture</name>
    <appEUI>0</appEUI>
    <columngroup title="SOILNET SOIL MOISTURE STATIONS GREECE PROJECT ATLAS" sensor="Box
Info" >
        <value>
            <name>RECV_TIMESTAMP</name>
            <title>Age</title>
            <unit>AGE</unit>
            <format>2006-01-02 15:04:05</format>
            <description>Recv time</description>
        </value>
        <value>
            <name>DEVICE_NAME</name>
            <title>name</title>
            <format>%s</format>
            <description>name of the device (for example "Box1")</description>
        </value>
        <value>
            <name>SOLAR</name>
            <title>s</title>
            <format>%s</format>
            <description>sensorbox charged via solar cell</description>
        </value>
            <value>
            <name>STATUS</name>
            <title>ST</title>
            <format>%s</format>
            <description>State of sensorbox (Test, Installed, etc.)</description>
```

```
</value>
```

4.4   Export config file

The exported format is described in one or more export configuration files. Here you can specify at which position which value in which format is written in an output file. The delimiter is also declared.

Example name:

/etc/soilnetloracpa/export-config/nbiot_1_export_db_format.xml

Example content:

```
<?xml  version="1.0"  encoding="UTF-8"?>
<exportformat>
    <name>NBIoT_Soilmoisture</name>
    <appEUI>0</appEUI>
    <version>V1.0.0</version>
    <date>18.02.2019</date>
    <delimiter>,</delimiter>
    <filename>NBIoT_1/db/NBIoT_1_YYYYMMDD_F01.csv</filename>
    <default>NaN</default>
    <value>
        <name>DEVICE_NAME</name>
        <format>%s</format>
        <description>name of the device (for example "Box1")</description>
    </value>
    <value>
        <name>TIMESTAMP</name>
        <format>060102150405</format>
        <description>Timestamp YYYYMMDDHHMMSS (time of the measurement)</description>
    </value>
    <value>
        <name>battery_0_0</name>
        <format>%d</format>
        <unit>mV</unit>
        <description>Box 3.6V Battery Voltage</description>
    </value>
…
```

4.5   Nbiot config file

The assignment of the incoming data stream to the respective application (type of device) is specified in this XML file.

The following has to be indicated:

1. Name of the device

2. Type of device (application ID)

3. IP address of the device

Fixed name:

/etc/soilnetloracpa/nbiot.xml

Example content:

```
<nbiot_config>

    <port>61556</port>

    <application id="1000">

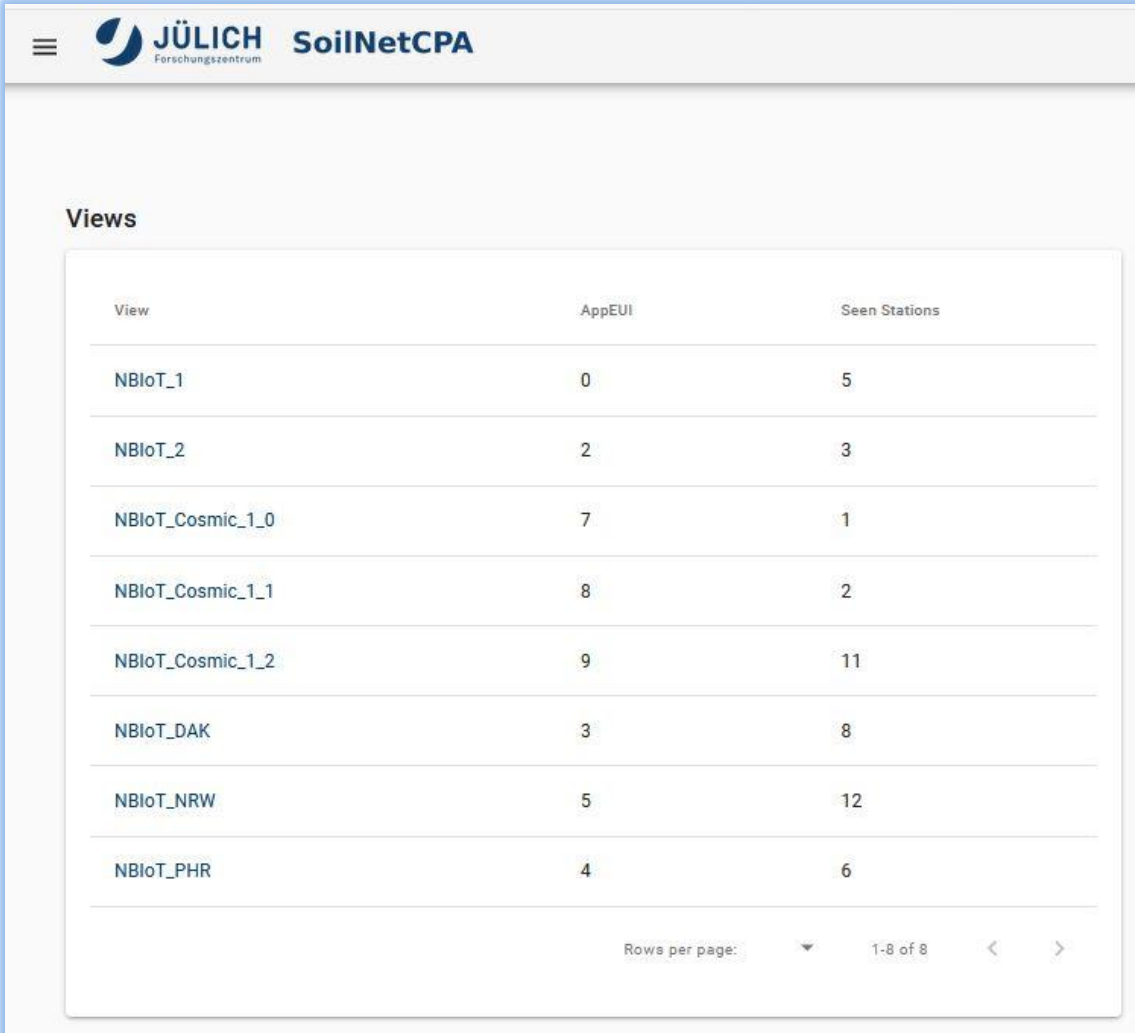        <node name="ED_AS_00" ip="100.106.109.5"/>

        <node name="ED_AS_01" ip="100.106.109.10"/>

        <node name="ED_AS_02" ip="100.106.109.9"/>

        <node name="ED_AS_03" ip="100.106.109.8"/>
```

Etc.

5   Web Live Status

The CPA software creates a tabular view of the last measured values on a web interface.

After called up the user interface (host ip address, port 80), there is first an overview of the "Views" available (assignment to AppEUI).

Figure 4: Views

This "Views" are the result from the view config files. Each file create a list entry for the associated AppEUI.

You can see the AppEUI and the number of devices belonging to this App.

Now you can choose the View you want to see.

View NBIoT_DAK

				Box Info							Sensor 1				Sensor 2				
											SMT100				SMT100				
Age	name	s	ST	b-bat	m-bat	CSQ	mcount	measure time	box time	unsend	count	perm	SWC	TS	count	perm	SWC	TS	co
●	↓	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
AGE				mV	mV								vol%	C°			vol%	C°	
1556s	ED_DAK_001	X	T	3428	3248	13	25834	2020-12-15 14:00:00	2020-12-15 14:00:29	0	15602	4.20	6.03	5.56	16004	3.61	4.54	5.67	13
1528s	ED_DAK_002	X	T	3411	3274	8	22371	2020-12-15 14:00:00	2020-12-15 14:00:56	0	12844	10.50	19.79	5.20	14036	7.26	13.17	5.06	13
5134s	ED_DAK_003	X	T	3368	3242	10	22364	2020-12-15 13:00:00	2020-12-15 13:00:49	0	11978	14.25	26.39	4.96	12669	10.97	20.69	5.05	13
1543s	ED_DAK_004	X	T	3384	3282	10	22363	2020-12-15 14:00:00	2020-12-15 14:00:42	0	12376	12.31	23.11	4.88	12814	10.19	19.20	4.98	13
1536s	ED_DAK_005	X	T	3396	3268	8	22352	2020-12-15 13:30:00	2020-12-15 14:00:44	2	11605	16.13	29.29	4.58	11897	14.66	27.04	4.67	12
1528s	ED_DAK_006	X	T	3423	3256	11	22291	2020-12-15 14:00:00	2020-12-15 14:00:56	0	12893	10.30	19.42	4.30	12190	13.19	24.64	4.38	12
1524s	ED_DAK_007	X	T	3390	3320	12	22290	2020-12-15 14:00:00	2020-12-15 14:01:00	0	12257	12.82	24.01	4.25	12188	12.98	24.27	4.35	12
1493s	ED_DAK_008	X	T	3412	3268	17	22781	2020-12-15 14:00:00	2020-12-15 14:01:32	0	12040	14.21	26.32	5.46	12427	12.62	23.65	5.77	12

Figure 5: Overview Devices

The table shows an overview of the sensor units. The entry age in seconds can be seen in the first line.

Depending on the configuration, the unit parameters and the sensor values are displayed here.

A grouping of the sensor values is possible and always makes sense if there are several measured variables from one sensor.

Coloured highlighting when a limit value is exceeded or not reached is also possible, this makes it easier to find abnormalities.

6   Location of files and data

Here you find the **data** export result files:

/var/lib/soilnetloracpa/

                Appname_1/…

                Appname_2/…

                etc.

Here you find the **config** files:

/etc/soilnetloracpa/

                export-config/…

                import-config/…

                node-config/…

                view-config/…

                nbiot.xml