LPWAN cellular connectivity on STEVAL-STWINKT1B for cloud condition monitoring-based applications

Introduction

Cellular low power wide area network (LPWAN) technologies are highly applicable in Industrial Internet of Things (IIoT) scenarios, especially those involving battery-powered sensor nodes that require wireless, low power and long-range connectivity. Condition monitoring and predictive maintenance applications can take advantage of LPWAN protocols such as NB-IoT and LTE-M to deliver affordable cloud monitoring solutions for industrial equipment when wired connectivity is not viable.

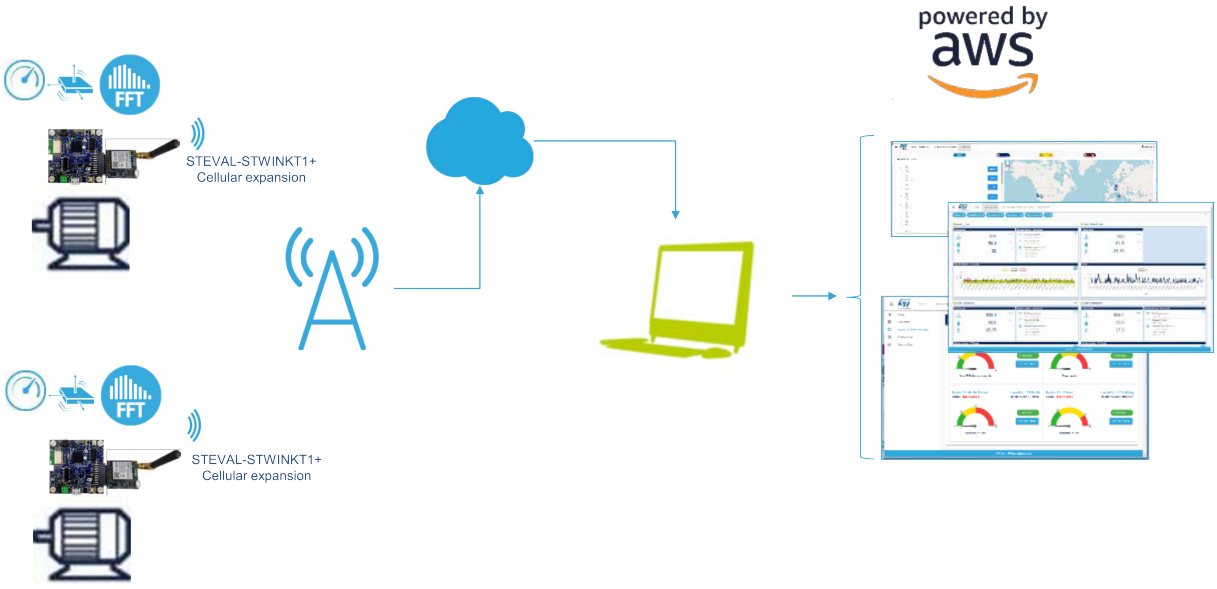
Narrow band Internet of Things (NB-IoT) is a standards-based, LPWAN technology that offers a wide range of services associated with connected objects. It can significantly reduce power consumption in user devices and still provide the necessary coverage for application control and data transmission services, including security and privacy support for user identity confidentiality, entity authentication, confidentiality, data integrity, and mobile equipment identification.

Long-term evolution machine type communication (LTE-M) offers better performance and can therefore complement NB-IoT when high data transmission speeds and terminal mobility are required, while the superior radioelectric coverage, lower costs and longer battery life offered by NB-IoT should be preferred when these services are not necessary.

The STSW-STWINCELL software package lets you test and develop a smart industrial condition monitoring sensor node connected to a cloud application based on Amazon Web Services (AWS) over innovative LPWAN cellular technologies such as NB-IoT and LTE-M. The firmware runs on the SensorTile Wireless Industrial Node (STEVAL-STWINKT1B) along with the STMod+ cellular expansion board with BG96 modem from Quectel (included in the P-L496G-CELL02 Discovery pack or available as STEVAL-STMODLTE).

Note: STEVAL-STMODLTE is available for US and Canada markets only.

Figure 1. ST Predictive Maintenance scenario using cellular networks



This cellular connectivity allows the STSW-STWINCELL firmware to publish smart, prepocessed data from STEVAL-STWINKT1B sensor nodes on the ST Predictive Maintenance Dashboard (DSH-PREDMNT) cloud application based on Amazon Web Services (AWS), from which you can gather, monitor and analyze critical vibration, ultrasound and environmental data on specific industrial equipment.

RELATED LINKS

Use Google Chrome to run the Predictive Maintenance Dashboard with your myST login credentials

1 Hardware and software requirements

Figure 2. **STEVAL-STWINKT1B with STMod+ cellular add-on board**

1.1 Hardware requirements

1. STEVAL-STWINKT1B STWIN SensorTile Wireless Industrial Node development kit
   - Core system board with industrial-grade sensors and ultra-low-power MCU
   - Li-Po battery 480 mAh
   - STLINK-V3MINI debugger with programming cable
   - Plastic box
2. Cellular STMod+ expansion board with Quectel BG96 worldwide cellular modem (LTE Cat M1/Cat NB1/ EGPRS module).

Note: The expansion board is available as STEVAL-STMODLTE or included in the P-L496G-CELL02 STM32 Discovery pack. The Discovery pack includes a Discovery MCU board that you can use to optimize the scanning and connection times of the BG96 modem on the cellular expansion board.

3. Micro-SIM (3FF) with M2M/NB-IoT profile
4. Windows PC

RELATED LINKS

7 Optimizing modem scanning and connection times on page 38

1.2 Software requirements

1. STSW-STWINCELL cellular to cloud connectivity software package.

2. X-CUBE-CELLULAR cellular connectivity software expansion for STM32Cube.

Note: This software is optional and can be used to optimize the scanning and connection times of the BG96 modem on the cellular expansion board.

3. Quectel LTE&5G Windows USB Driver. This software is optional and offers an alternative way to optimize the BG96 module scanning and connection times.
4. STM32CubeProg, an all-in-one multi-OS software tool for programming STM32 products, to erase and program the flash memory of the microcontroller
5. IDE for STM32 to rebuild the projects
   - IAR Embedded Workbench V8.32.3
   - Keil MDK-ARM V5.27.1
   - STM32CubeIDE V1.2.0
6. Terminal emulator program (e.g. Tera Term)
7. DSH-PREDMNT Predictive Maintenance Dashboard AWS cloud application

RELATED LINKS

Use Google Chrome to run the Predictive Maintenance Dashboard with your myST login credentials

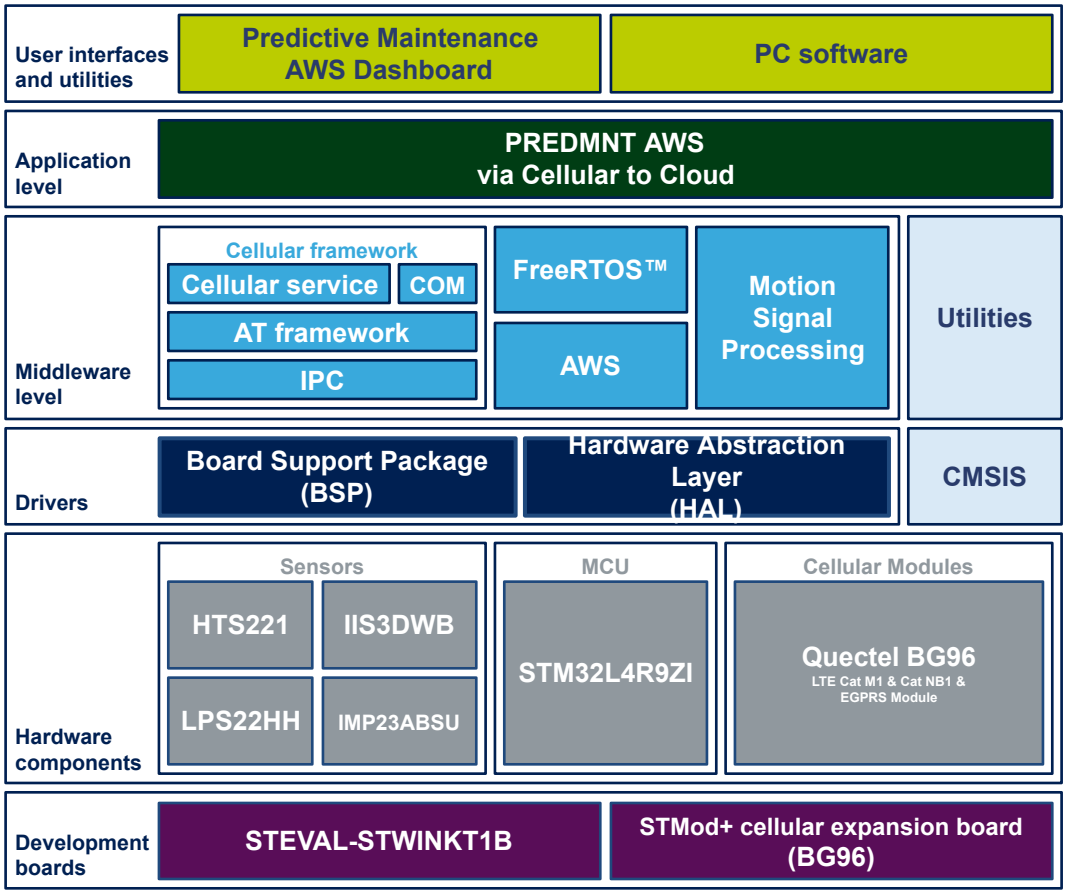
7 Optimizing modem scanning and connection times on page 38

2 Firmware

2.1 Architecture

The STSW-STWINCELL software package is a set of libraries and embedded software blocks available to enable fast and easy development on the STM32 platform.

Figure 3. STSW-STWINCELL firmware architecture



- Board Support Package (BSP): set of APIs related to the hardware components on the boards.
- Hardware abstraction layer (HAL): low-level drivers and the hardware interfacing methods to interact with the upper layers.
- Cortex Microcontroller Software Interface Standard (CMSIS): enables consistent device support and simple software interfaces to the processor and its peripherals.
- Middleware components: set of libraries for specific algorithms, communication interface and real time operating system.

2.2 Folder structure

STSW-STWINCELL

This software package is developed using the standard STM32Cube framework structure shown below:

```
\STSW-STWINCELL
├──_htmresc
├──Documentation
├──Drivers
├──Middlewares
├──Projects
└──Utilities
```

_htmresc

This folder contains the html resources.

Documentation

This folder contains the documentation.

Drivers

This folder contains the following main groups:

```
├──Drivers
│   ├──BSP
│   ├──CMSIS
│   └──STM32L4xx_HAL_Driver
```

BSP

The board specific drivers for whole the HW components. The BSP files are grouped in folders that include all the hardware device low level drivers as well as all specific board medium level drivers.

```
│   ├──BSP
│   │   ├──Components
│   │   ├──Modems
│   │   └──STWIN
```

Components

The Components folder includes a set of platform-independent device drivers and their common files.

```
│   │   ├──Components
│   │   │   ├──Common
│   │   │   ├──hts221
│   │   │   ├──iis3dwb
│   │   │   └──lps22hh
```

Modems

The Modems folder includes a set of platform-independent drivers to manage the related AT commands.

```
│   │   ├──Modems
│   │   │   ├──BG96_STMOD+
│   │   │   │   └──AT_modem_bg96
│   │   │   └──UG96_STMOD+
│   │   │       └──AT_modem_ug96
```

STWIN

The STWIN folder includes a set of medium level drivers for each hardware subsystem running on this board (e.g., audio, environmental, motion, etc.).

```
|   |   ├──Modems
|   |   |   ├──BG96_STMOD+
|   |   |   |   └──AT_modem_bg96
|   |   |   └──UG96_STMOD+
|   |   |       └──AT_modem_ug96
```

CMSIS Vendor-independent hardware abstraction layer for ARM Cortex-M series, including DSP Libraries used for all projects.

STM32L4xx_HAL_Drivers Microcontroller HAL libraries.

Middlewares This folder contains libraries oriented to provide, at high application level, specific APIs:

```
├──Middlewares
|   ├──ST
|   |   ├──STM32_Cellular
|   |   ├──STM32_Connect_Library
|   |   ├──STM32_MotionSP_Library
|   └──Third_Party
|       ├──AWS
|       ├──FreeRTOS
|       ├──jsmn
|       ├──mbedTLS
|       └──parson
```

STM32_Cellular Provides a Cellular Framework that is the software stack that allow to drive cellular modem from STM32 MCU.

STM32_Connect_Library Provides API to access network services on STM32 devices.

STM32_MotionSP_Library Provides algorithms to analyze vibration in both time domain and frequency domain using data coming from accelerometer.

AWS Provides the AWS IoT device SDK for embedded C that is a collection of C source files which can be used in embedded applications to securely connect to the AWS IoT platform.

FreeRTOS Provides a real-time operating system kernel for embedded devices. It is distributed under the MIT License.

jsmn Provides a minimalistic JSON parser in C.

mbedTLS Provides cryptographic and SSL/TLS capabilities.

parson Provides a lightweight json library written in C.

Projects This folder contains the user level files of the application software:

```
├──Projects
│   ├──Demonstrations
│   │   └──C2C
│   │       └──AWS
│   │           ├──Binary
│   │           │   ├──STSW-STWINCELL_BG96_Vx.y.z.bin
│   │           │   └──STSW-STWINCELL_UG96_Vx.y.z.bin
│   │           ├──EWARM
│   │           ├──Inc
│   │           ├──MDK-ARM
│   │           ├──Src
│   │           └──STM32CubeIDE
│   ├──Utilities
│   │   ├──CLD_utils
│   │   ├──Misc_Utils
│   │   └──Time
```

Binary The Binary folder contains the firmware images, referred to the modem to be used, ready to download into the MCU flash memory.

Inc and Src Inc and Src folders contain the application files.

EWARM IDE folder for IAR Embedded Workbench development environment

MDK-ARM IDE folder for Keil MDK-ARM development environment

STM32CubeIDE IDE folder for STM32CubeIDE development environment

Misc_Utils Misc_Utils contains application utilities.

Utilities This folder contains the useful tool for running the demo (e.g. tera term).

2.3 Application behavior

The firmware process management is controlled by an RTOS. The application is managed by tasks, semaphores, queues and messages.

Before the `osKerneStart()` OS scheduler is started, the only task created is `MainThread(…)`, which initializes the platform, followed by the network, security, and the sensors along with their corresponding tasks.

Just before `MainThread(…)` terminates, it creates the `cloud_run(…)` application task, which starts the connection handshake with AWS cloud and initiates all the structures associated with data transmission. Once the handshake is performed, the cloud connection is managed as an infinite loop. If an error occurs, the loop is bypassed and the `Error_Handler()` function runs.

Regarding the streaming times set on the dashboard, the environmental, inertial and acoustic data is prepared by the `publish_scheduler_callback(…)` function that is called every 1000 ms. In the scheduler function, a queue identifying the current feature is set. This queue is retrieved by the OS for the application task (i.e., `cloud_run`), so the data can be published on the cloud dashboard according to the dashboard streaming time.

The different types of data from the SensorTile Wireless Industrial Node are managed by the following functions:

- `AUDIO_OS_Init()`: for ultrasound analysis data, managed using threads, semaphores and messages created in the function. DMA and interrupts are also used.
- `ine_init()`: for inertial analysis data, managed using a thread and a semaphore created inside the function. External interrupt lines are also used.

- The environmental data is called on demand by an ad hoc task and not at regular intervals.

The tasks for acoustic and inertial analysis are run sequentially.

The required features can be selected in the `aws_iot_config.h` file. The user can choose any or all of the following features by toggling the value of the following keywords:

- USE_ENV_FEAT
- USE_INE_TDM_FEAT
- USE_INE_FDM_FEAT
- USE_ACO_FEAT

RELATED LINKS

5 How to activate the ST Predictive Maintenance Dashboard on page 20

6 Demonstration application on page 25

2.4 IDE configuration selection

Each project comes with a separate configuration for each modem to be used.

Figure 4. IAR configuration selection

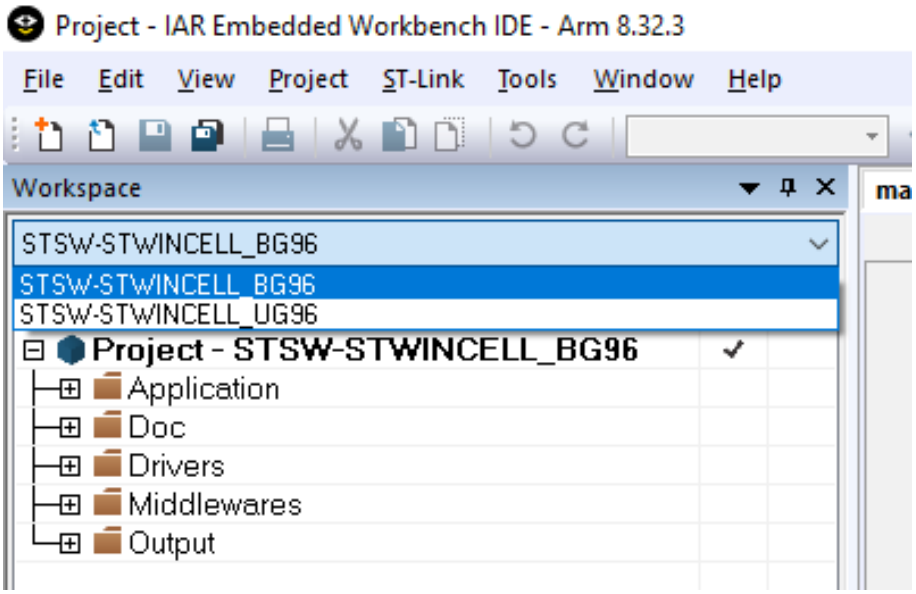


Figure 5. **Keil configuration selection**

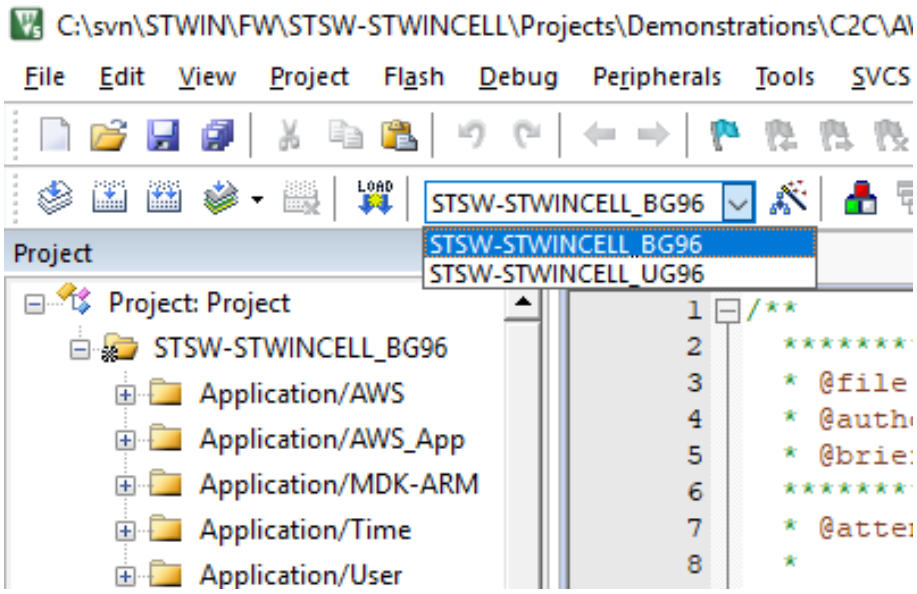
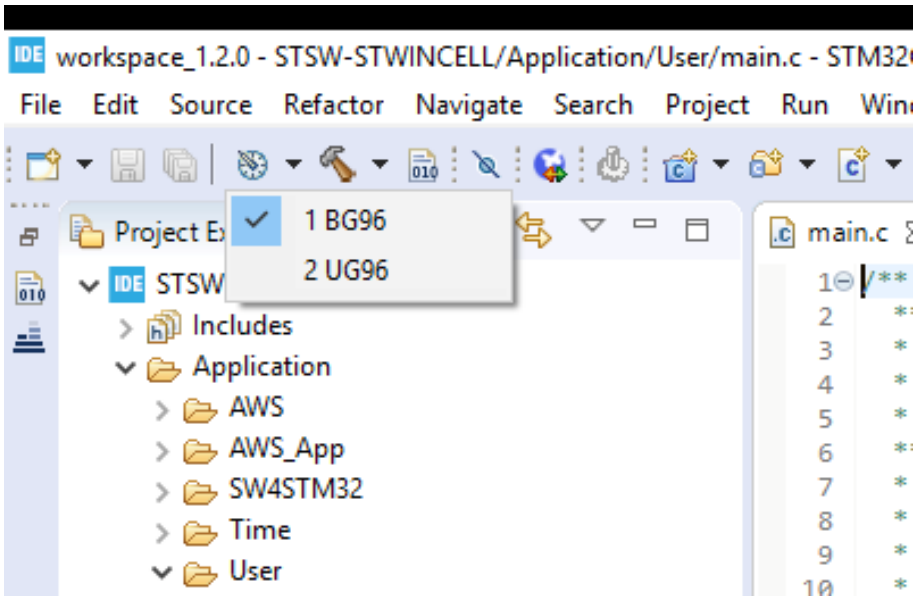


Figure 6. **STM32CubeIDE configuration selection**

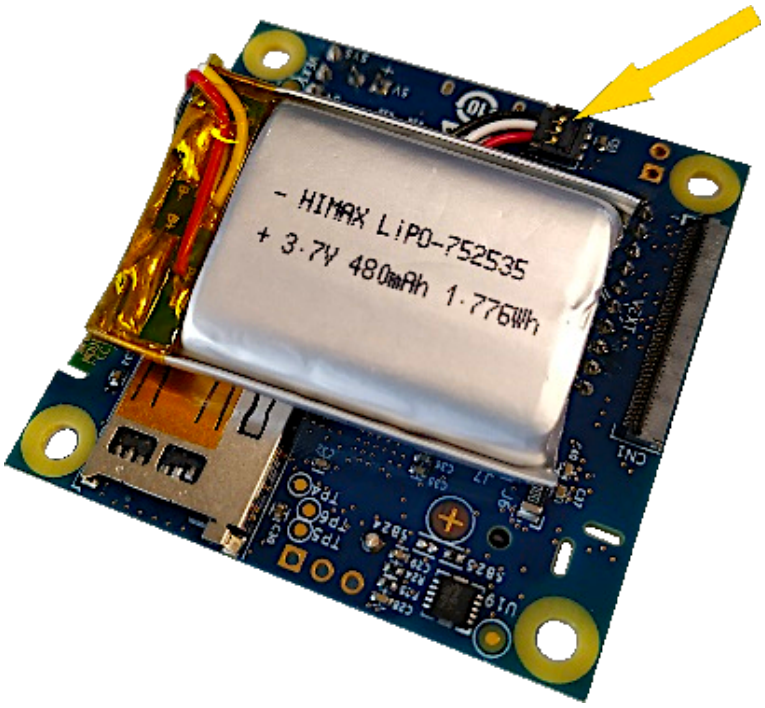


3 Hardware setup

3.1 Set up and power supply

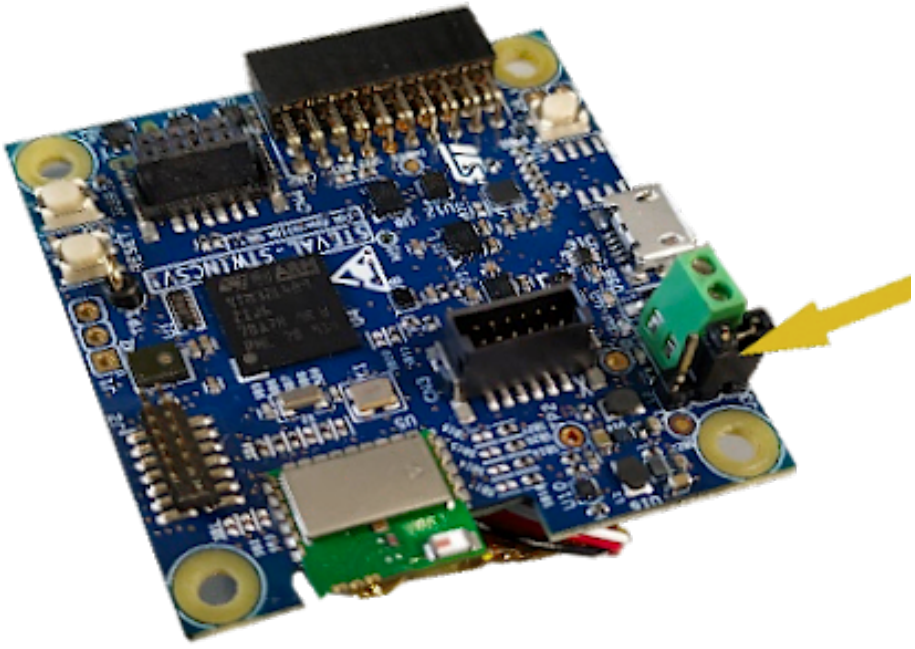
Step 1. Connect the battery to the STEVAL-STWINKT1B.

Figure 7. STEVAL-STWINKT1B battery connection



Step 2. Route the external unregulated supply pin of the battery charger to the power supply pin of the STMod+ connector (short pins 2-3 of J3).

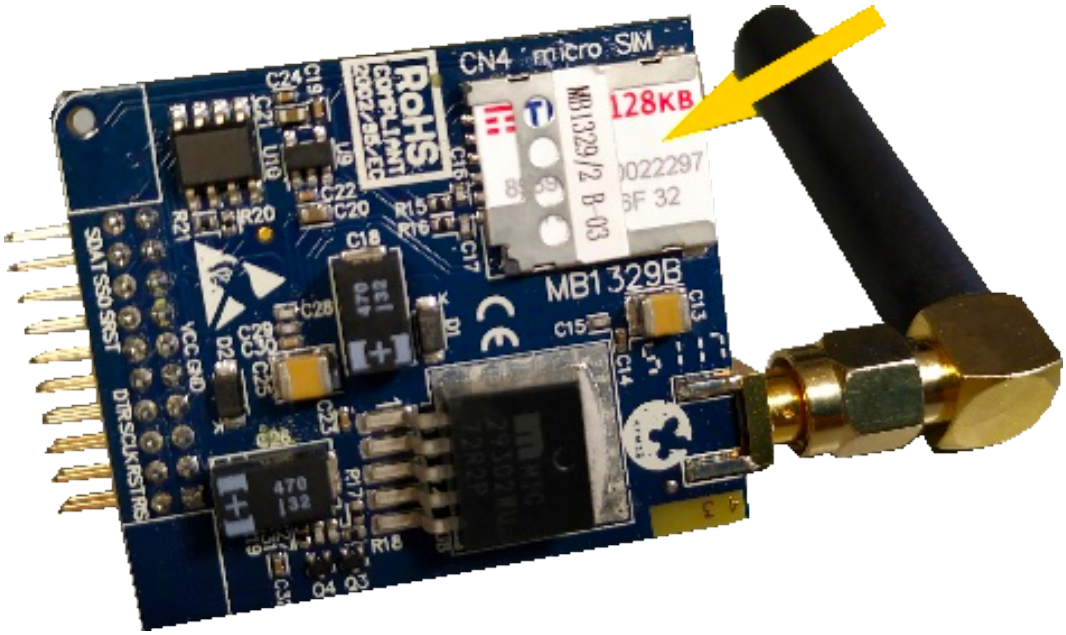
Figure 8. STEVAL-STWINKT1 STMod+ power supply selection



Step 3. Mount the STEVAL-STWINKT1B with the battery in the plastic box.

Step 4. Insert the SIM card into the appropriate socket on the cellular expansion board.

Figure 9. SIM mounted on BG96 cellular add-on board

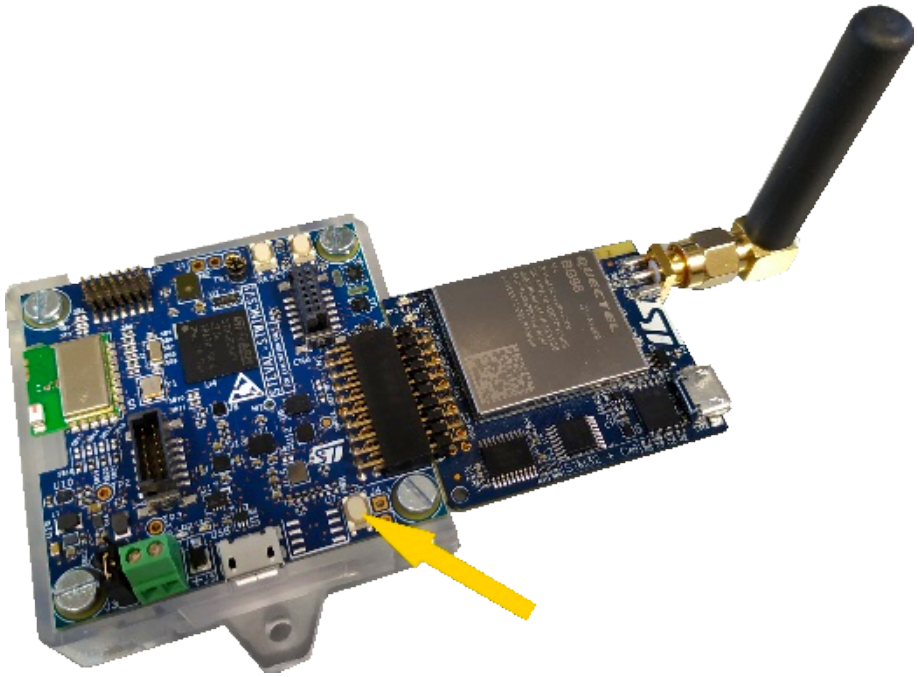


Step 5. Plug the cellular expansion board in the STMod+ connector.

Step 6. Power on the kit.

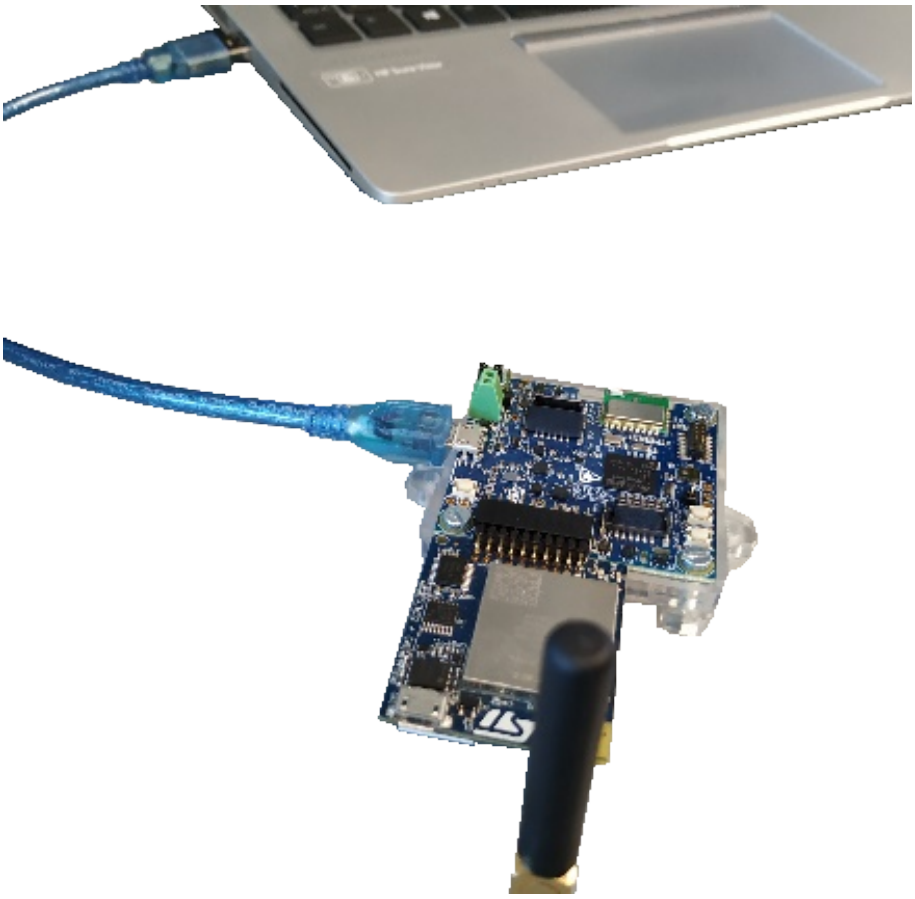
– If powered via battery, press the PWR button on the STEVAL-STWINKT1B for more than 2 seconds.

Figure 10. STEVAL-STWINKT1B start in battery mode



– If powered through USB, just connect a micro USB cable between the micro USB socket of the STEVAL-STWINKT1B and a USB port with at least 1 A of current capability.

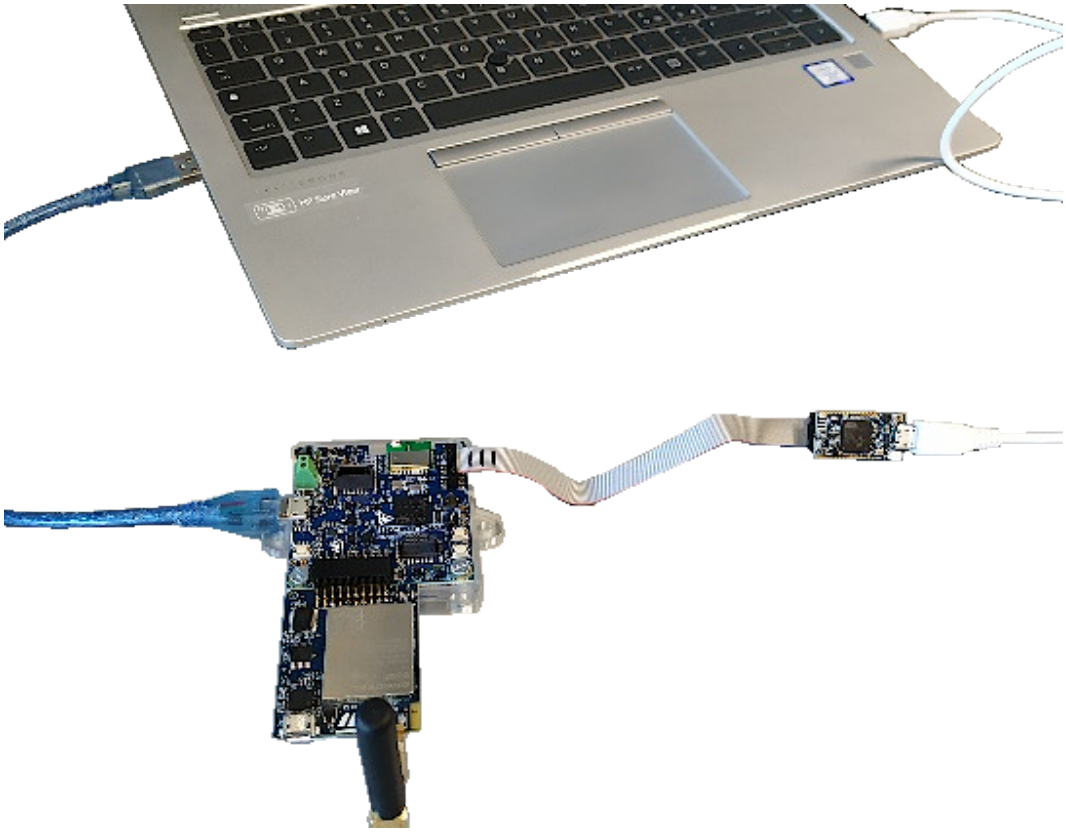
Figure 11. **STEVAL-STWINKT1B start in USB mode**



Step 7. Connect the STEVAL-STWINKT1B and the STLINK-V3MINI debugger with the 14-pin programming cable plugged on J2.

Step 8. Connect the STLINK-V3MINI debugger to a USB port on your PC via a micro USB cable.

Figure 12. STEVAL-STWINKT1B connected to STLINK-V3MINI



Step 9. Turn off the board.

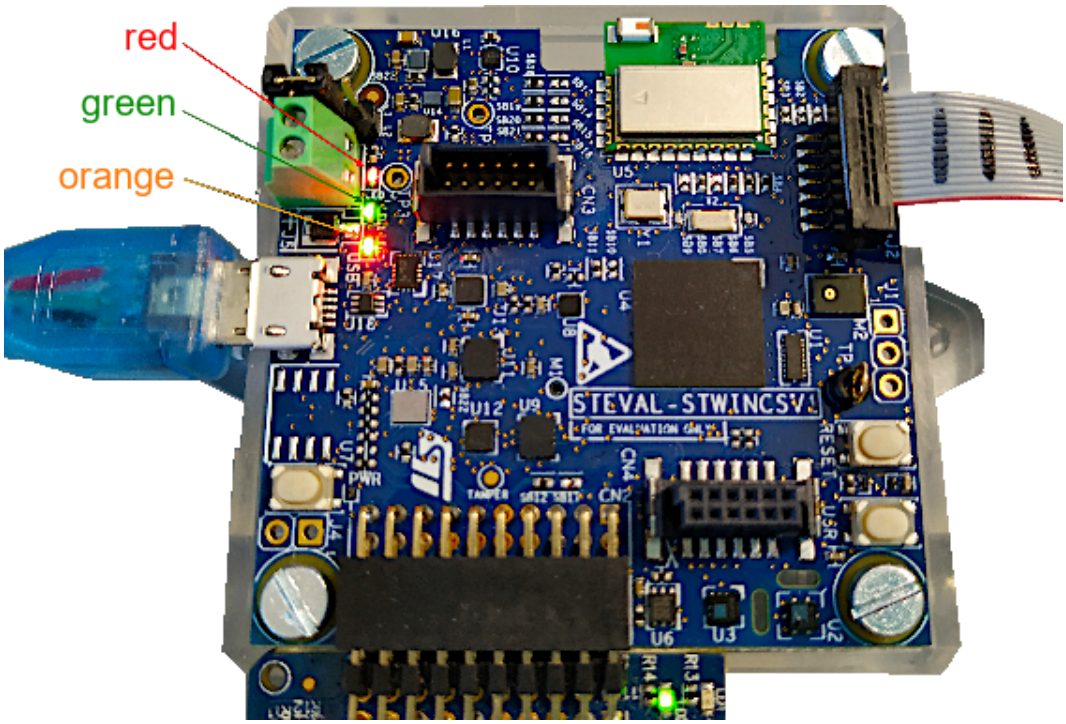
- If the board is only powered by the Li-Po battery, hold down the PWR button for more than 3 seconds (SW feature).
- If the board is only powered via USB, unplug the micro USB cable.

3.2 Status LEDs

The STEVAL-STWINKT1B has the following status LEDs.

- Red LED
  - STBC02 Battery Charger status information.
- Green LED
  - Flashes slowly (once per second) after MQTT connection is established
  - Flashes quickly (every 200 ms) after an error has occurred.
- Orange LED
  - lights up at power on
  - flashes while data is publishing.

Figure 13. **STEVAL-STWINKT1B LEDs**



3.3 Note on battery operation

TheSTEVAL-STMODLTE STMod+ cellular expansion board used in this demo is designed to be supplied by 5 V USB input voltage only. As the Quectel module requires a 3.3 V to 4.3 V working input voltage, the STMod+ cellular expansion board comes with a configurable LDO designed to provide 3.8 V by means of a voltage divider.

This does not create any issues when the same cellular expansion board is plugged into an STEVAL-STWINKT1B powered via USB, but when the STEVAL-STWINKT1B is only powered by a lithium battery, the input voltage provided to the STMod+ cellular expansion board is nominally 3.7 V, which is below the voltage the LDO was designed to output.

In this case, the LDO is not able to correctly regulate the voltage at 3.8 V, but simply replicates the input voltage to output with a low drop. The system still functions normally because the Quectel module minimum operating voltage is 3.3 V, but any voltage ripple cannot be filtered.

4 Firmware setup

Before you begin, you must ensure the hardware is configured appropriately.

RELATED LINKS

3.1 Set up and power supply on page 11

4.1 How to upload the firmware to the microcontroller

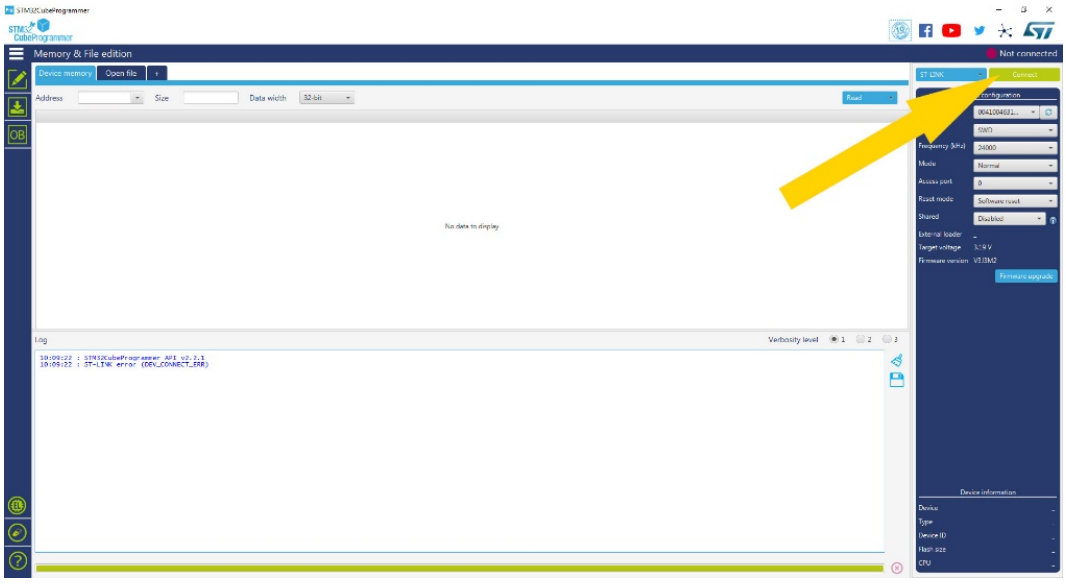
Follow the procedure below to load the demonstration firmware onto STEVAL-STWINKT1B and the STMod+ cellular expansion board.

Step 1. Download and unpack the STSW-STWINCELL firmware.
As long path lengths can cause issues, it is advisable to unpack it on or near your root directory.

Step 2. Run the STM32CubeProgrammer.

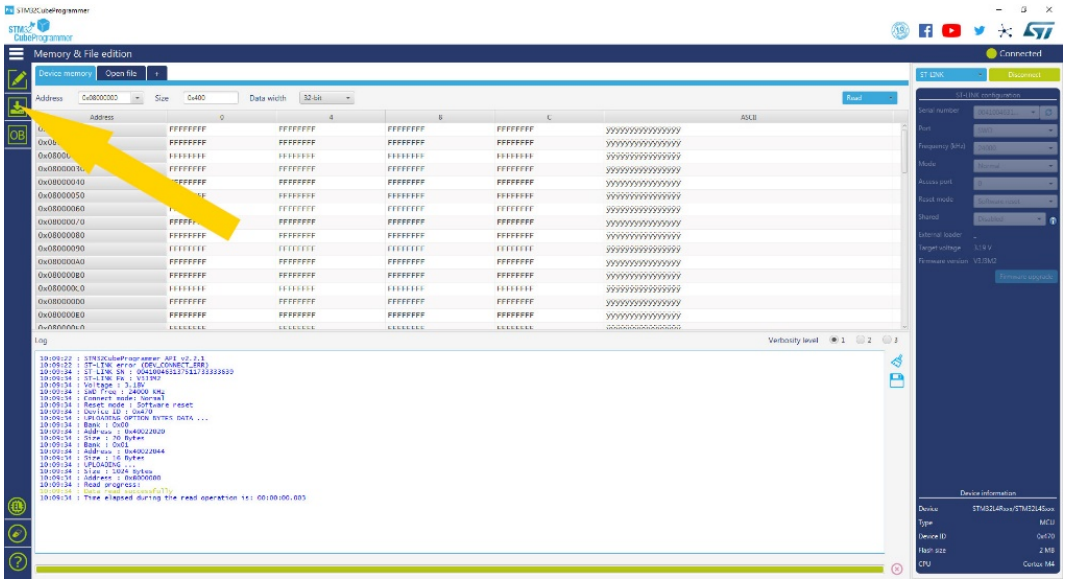
Step 3. Click [**Connect**]

Figure 14. STM32CubeProgrammer start-up mask



Step 4. Click [**Erasing & Programming**]

Figure 15. STM32CubeProgrammer connected mask

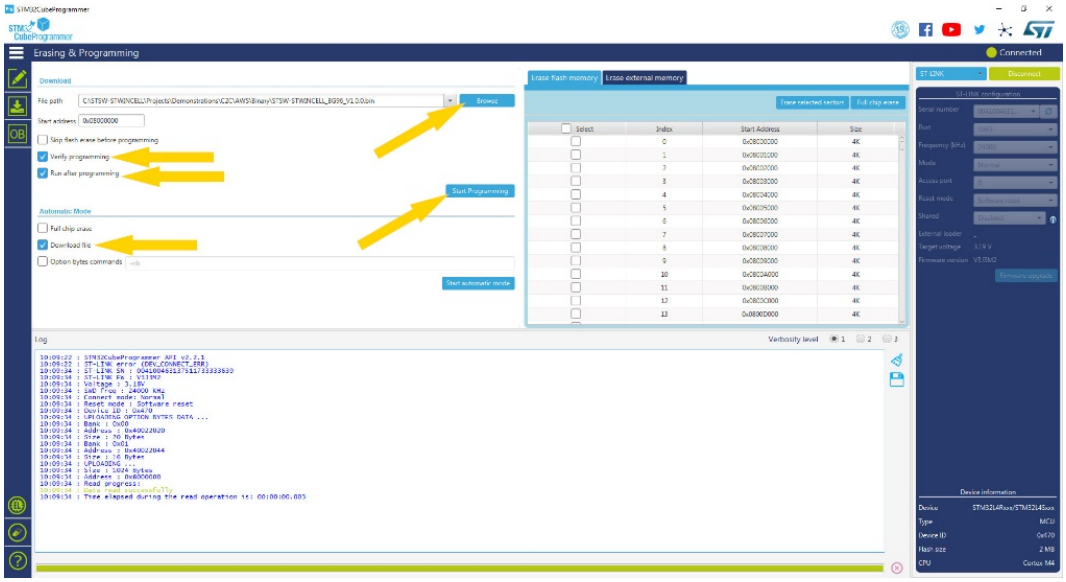


Step 5. Choose the appropriate (cellular module name) pre-built binary located in the STSW-STWINCELL\Projects\Demonstrations\C2C\AWS\Binary\ folder.

Step 6. Check the [**Verify programming**], [**Run after programming**] and [**Download file**] boxes

Step 7. Click [**Start Programming.**]

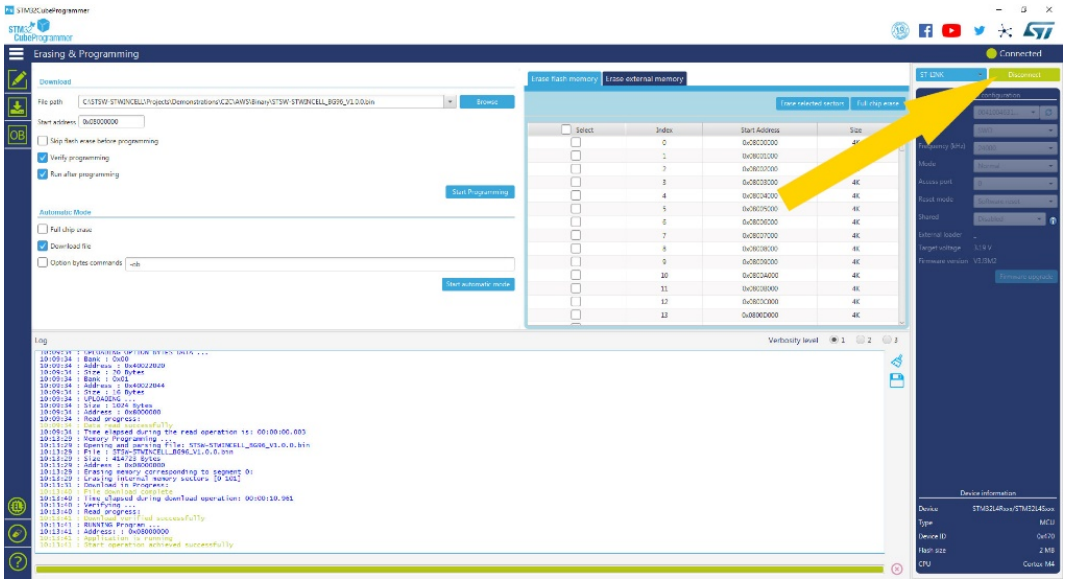
Figure 16. STM32CubeProgrammer Erasing & Programming mask



Step 8. Close all pop-up message windows

Step 9. Click [**Disconnect**]

Figure 17. STM32CubeProgrammer Erasing & Programming completed



5 How to activate the ST Predictive Maintenance Dashboard

The STSW-STWINCELL software package publishes data from the STEVAL-STWINKT1B with cellular connectivity on ST Predictive Maintenance Dashboard based on AWS IoT (Amazon Web Services internet of things) platform.

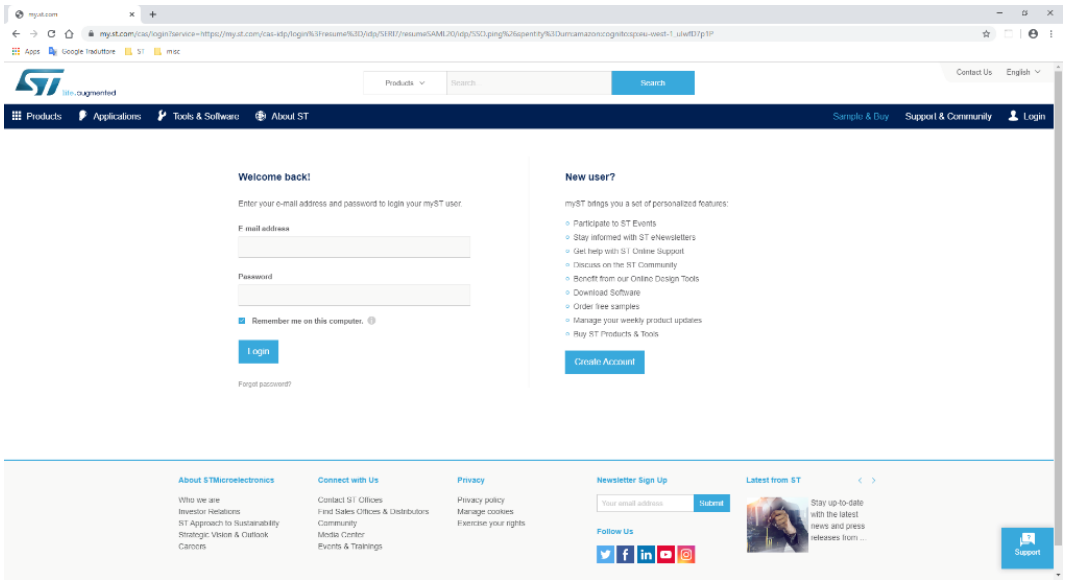
You can configure the firmware to publish any or all of the following data:

1. Vibration signal preprocessing in the time domain
2. Vibration signal preprocessing in the frequency domain
3. Environmental values as humidity, pressure and temperature
4. Sound preprocessing in the frequency domain.

Note: By default, all the features are enabled to be published.

Step 1. Open the following location with Google Chrome: https://dsh-predmnt.st.com/

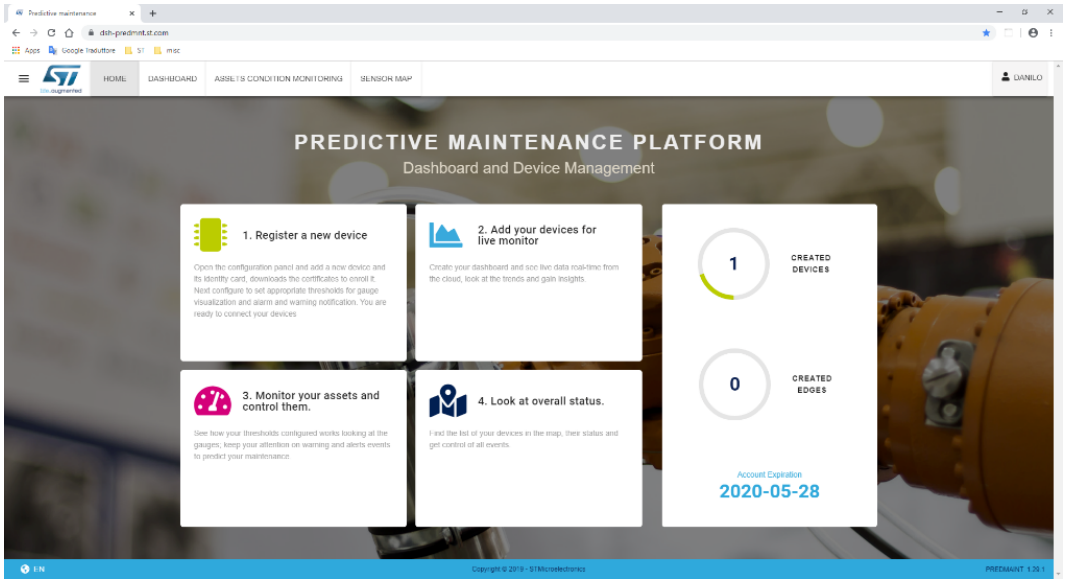
Figure 18. mySST login page



Step 2. Log in to the ST Predictive Maintenance Dashboard with your myST credentials

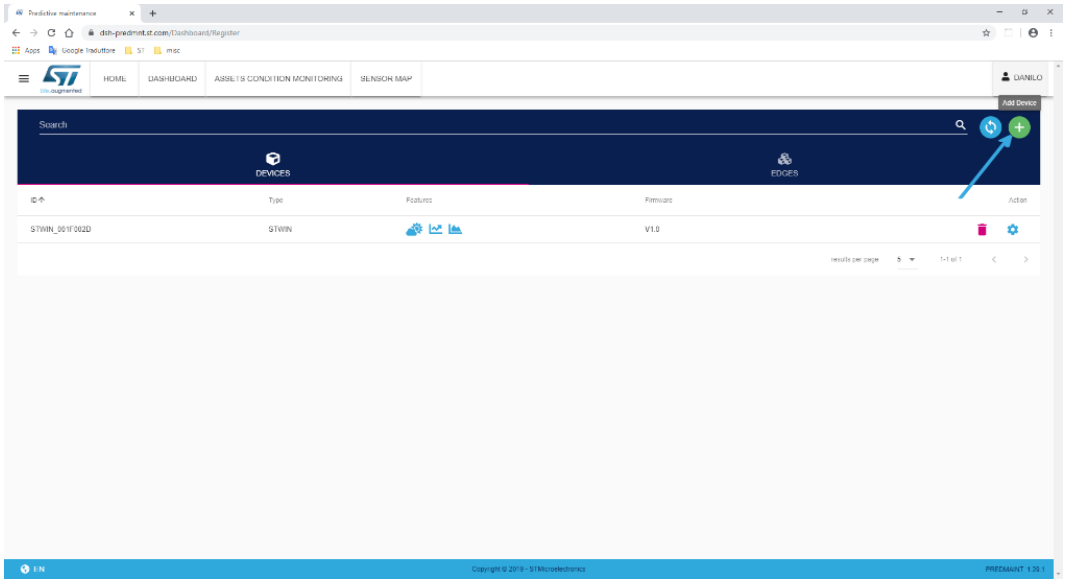
Once you log in, you can create new devices and manage any previous devices you have already created.

Figure 19. DSH-PREDMNT home page



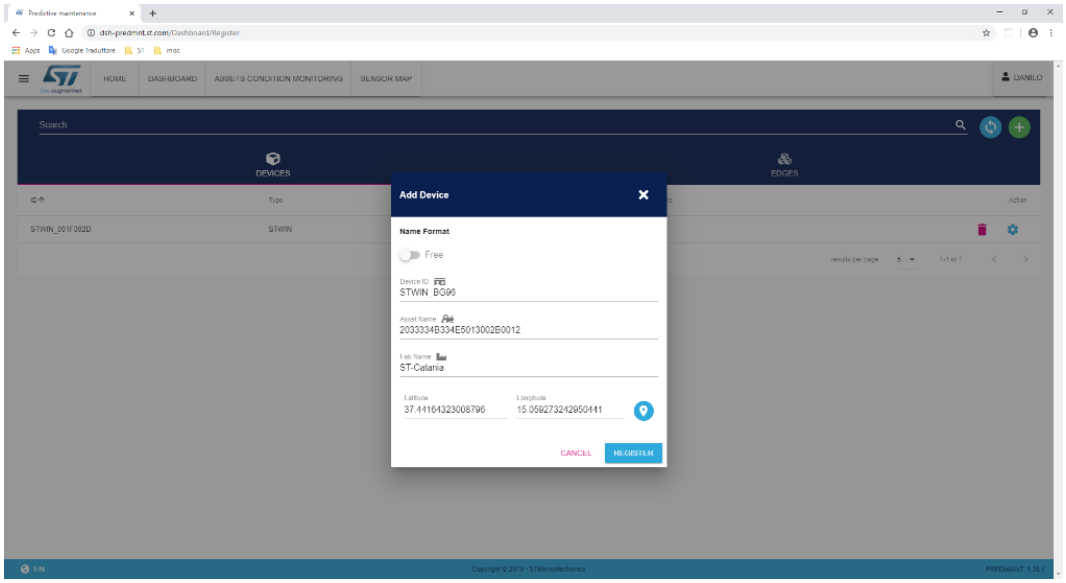
Step 3. Click [**Register a new device**].

Figure 20. DSH-PREDMNT register page



Step 4. Click on [**Add Device**] and fill in the information on the pop-up window.

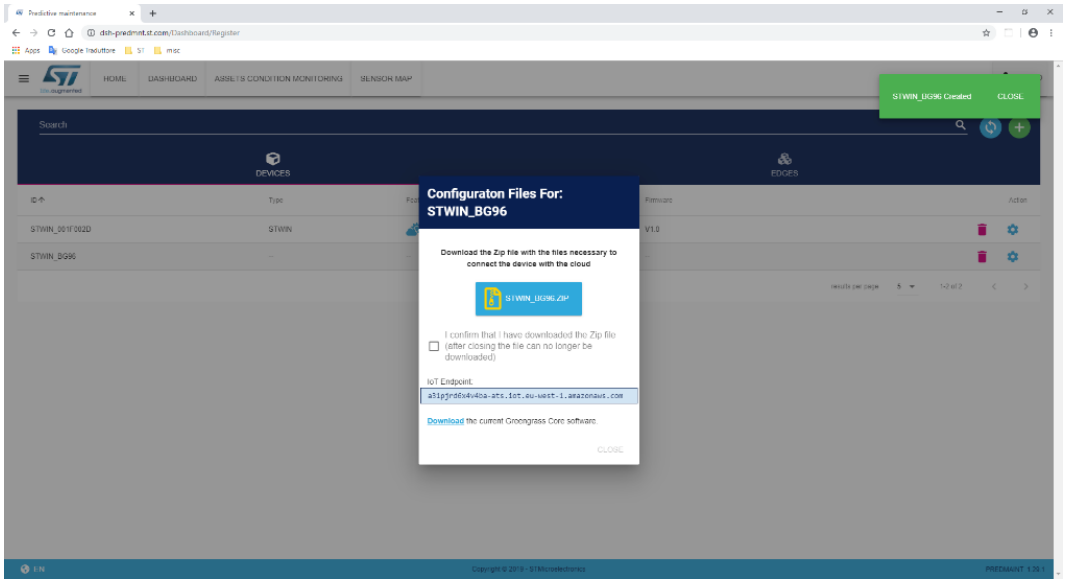
Figure 21. DSH-PREDMNT add device



Step 5. Then click [**Register**]

A new pop-up window confirms the device creation and provides a link to download the files for connecting the device with the cloud and the IoT Endpoint.

Figure 22. DSH-PREDMNT configuration file download for new device



Step 6. Download the zip file and note of the IoT Endpoint.

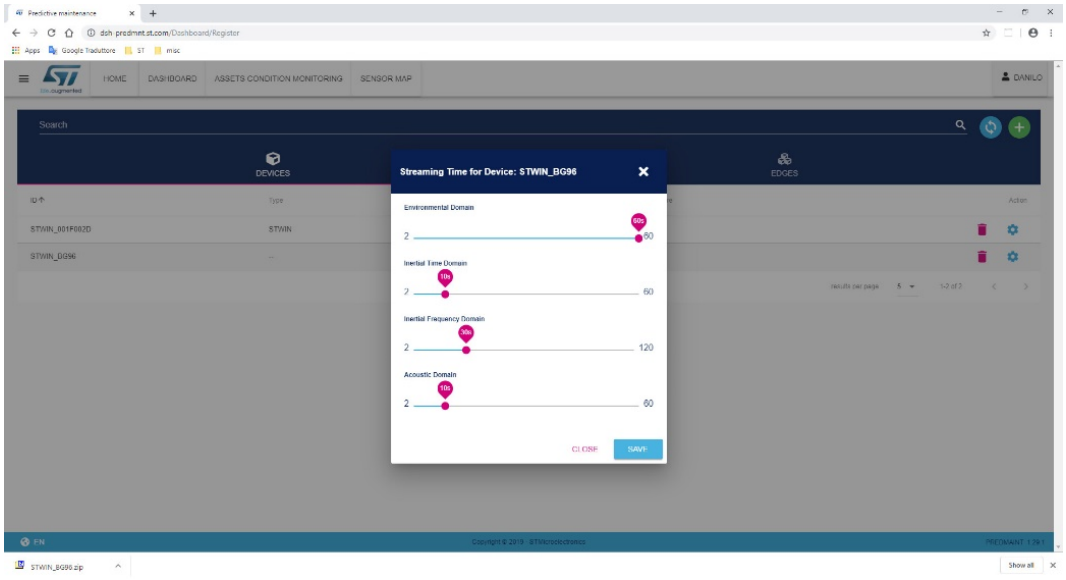
Note: The file can no longer be downloaded.

Step 7. click [**CLOSE**].

Step 8. Click on the gear icon for the corresponding device.

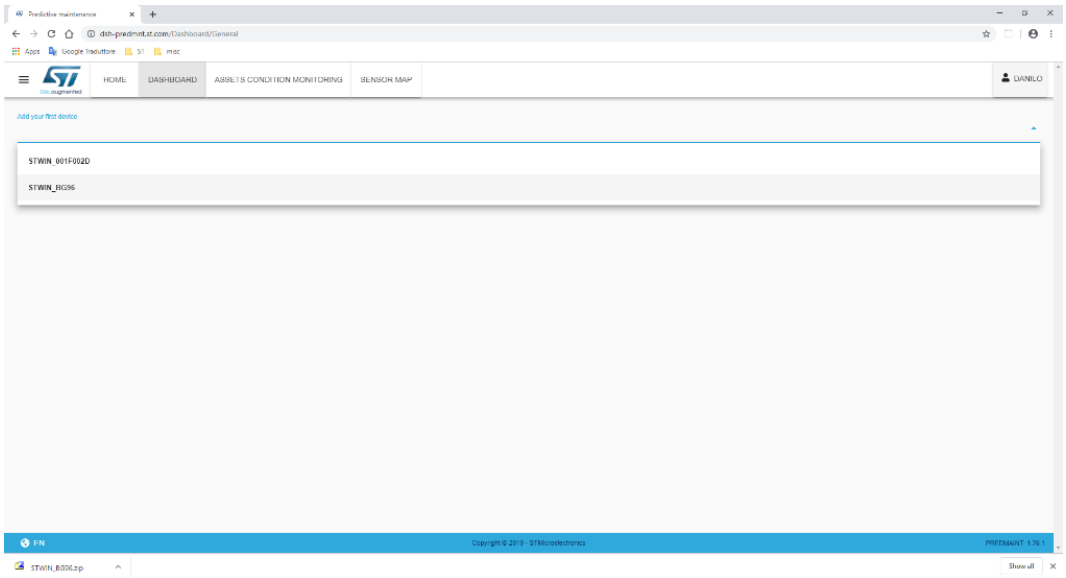
Step 9. Change the streaming time as shown in the figure below.
It also possible to set the thresholds to be monitored.

Figure 23. DSH-PREDMNT set streaming time



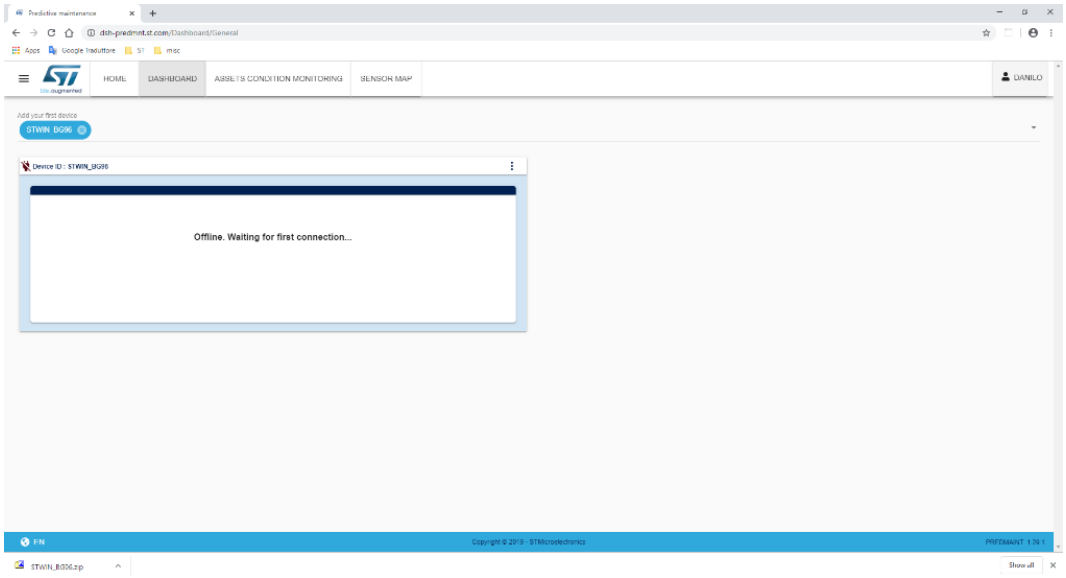
Step 10. Add the new device to the dashboard by selecting the corresponding tab.

Figure 24. DSH-PREDMNT add device to the dashboard



Step 11. The dashboard is now standing by for connection with the STEVAL-STWINKT1B sensor node.

Figure 25. DSH-PREDMNT dashboard waiting for first connection



RELATED LINKS

The DSH-PREDMNT web folder has several resources, including a user manual and a quick Getting Started guide.

6 Demonstration application

Before you use the demonstration application, you must set up the hardware and load the configured firmware onto the microcontroller.

RELATED LINKS

3.1 Set up and power supply on page 11
4 Firmware setup on page 17

6.1 How to set up and use the demo application

Step 1. Start Tera Term (or other similar terminal emulator software)

Step 2. Select the appropriate COM port and set the parameters as shown:

Figure 26. Tera Term Terminal setup

- [**New line**]
  - [**Receive**]: AUTO
  - [**Transmit**]: LF

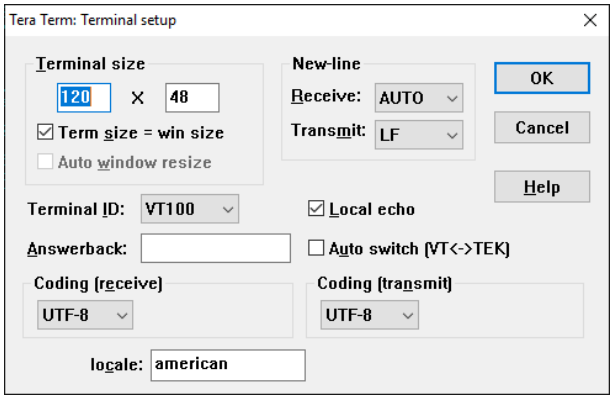
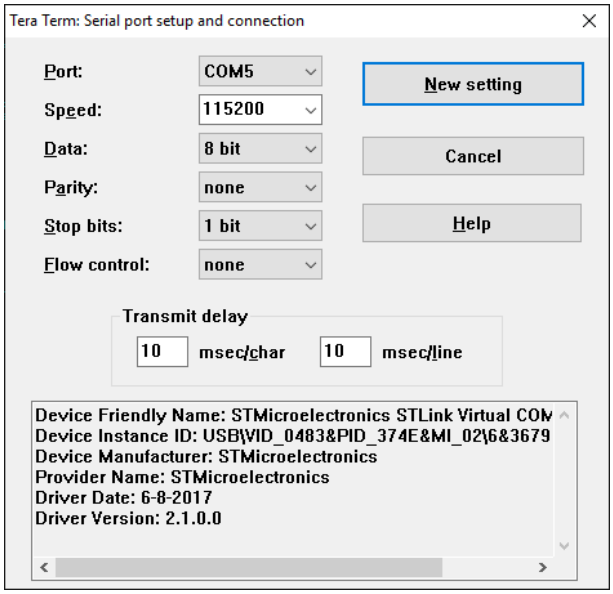


Figure 27. Tera Term Serial setup

- [**Baud rate**]: 115200
- [**Data**]: 8 bit
- [**Parity**]: none
- [**Stop**]: 1 bit
- [**Flow control**]: none
- [**Transmit delay**]: 10 ms each



Step 3. Press the reset button on the STEVAL-STWINKT1B.
The terminal console should show the following output:

```
************************************************************
***   STWIN - SensorTile Wireless Industrial Node
***      STM32L4R9Z MCU
***   Predictive Maintenance AWS Cloud Demonstration
***   Dashboard URL is https://dsh-predmnt.st.com
***   STSW-STWINCELL V1.0.0 - 13-February-2020
***   CMSIS Core(M) V5.1
***   HAL V1.10.0 RC0
***   Compiled Feb 13 2020 18:39:08 (IAR)
************************************************************
*** Board personalization ***
    A cellular expansion board, MB1329B, provided with the BG96 module
    have to be plugged into the STMOD+ connector.
    MCU Unique device ID is 0x2033334B334E5013002B0012
- Network Interface initialized:
Your Cellular parameters need to be entered to proceed.
Select the SIM slot (0 - External, 1 - Internal):
```

Step 4. Choose the SIM slot you are going to use
In this example, the external SIM slot is used

Step 5. Insert the APN for the cellular network operator you are going to use, as well as the optional credentials.
The cellular module will initialize and register the network

```
- Network Interface initialized:
Your Cellular parameters need to be entered to proceed.
Select the SIM slot (0 - External, 1 - Internal): 0
You have selected the external SIM.
Enter Sim Operator Access Point Code (e.g. EM or ESEYE1 etc): nbiot.tids.tim.it
You have entered <nbiot.tids.tim.it> as the Sim Operator Access Point Code.
Enter the username (it can be NULL) (max 16 char):
You have entered <> as the username.
Enter the password (it can be NULL) (max 16 char):
You have entered <> as the password.
- Network Interface starting:
*** C2C connection ***
Initializing the cellular module
- Network Interface connecting:
Trying to connect with the external SIM
Waiting for BG96 modem running
Signal not known or not detectable yet (be patient)
.....................................................
Signal Level: -77 dBm
........
C2C module registered
Registration done in 60025 msseconds
Retrieving the cellular operator: "I TIM"
Module initialized successfully: Quectel
ProductID: BG96
FW version: BG96MAR02A09M1G
SIM Id (IccID): 89390100002229786797
- Network Interface started:
   - Device Name : Quectel.
   - Device ID : BG96.
   - Device Version : BG96MAR02A09M1G.
- Network Interface connected:
   - IP address :  10.18.44.41.
Enter server address: (example: xxx.iot.region.amazonaws.com)
```

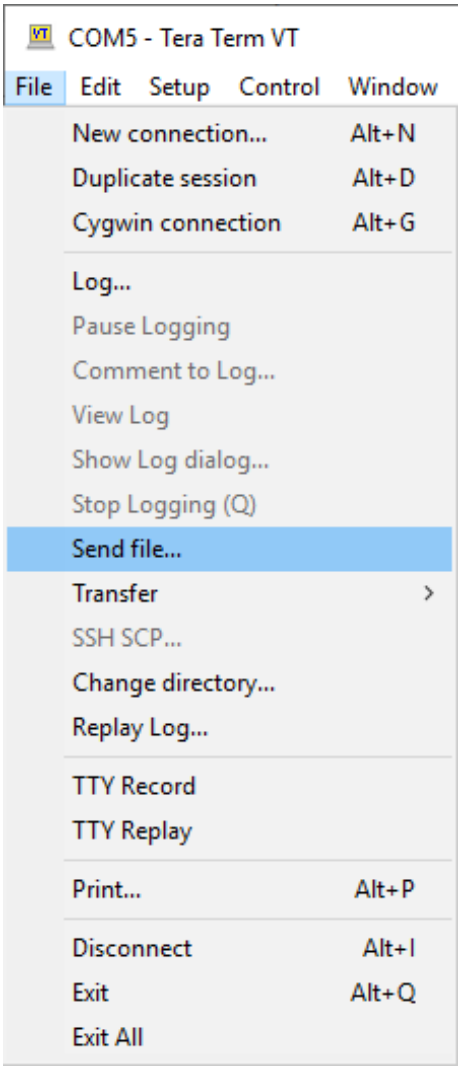
Step 6. Enter the IoT Endpoint information.
This information is shown during device creation phase on ST Predictive Maintenance Dashboard.

Step 7. Enter the name of the device.

```
Enter server address: (example: xxx.iot.region.amazonaws.com)
a31pjrd6x4v4ba-ats.iot.eu-west-1.amazonaws.com
read: --->
a31pjrd6x4v4ba-ats.iot.eu-west-1.amazonaws.com
<---
Enter device name: (example: mything1)
STWIN_BG96
read: --->
STWIN_BG96
<---
Updating TLS security credentials.
Enter the x509 certificates or keys as per the following format:
-----BEGIN CERTIFICATE-----
YMPGn8u67GB9t+aEMr5P+1gmIgNb1LTV+/Xjli5wwOQuvfwu7uJBVcA0Ln0kcmnL
R7EUQIN9Z/SG9jGr8XmksrUuEvmEF/Bibyc+E1ixVA0hmnM3oTDPb5Lc9un8rNsu
.......
-----END CERTIFICATE-----
-----BEGIN CERTIFICATE-----
YMPGn8u67GB9t+aEMr5P+1gmIgNb1LTV+/Xjli5wwOQuvfwu7uJBVcA0Ln0kcmnL
.......
-----END CERTIFICATE-----
.......
Enter your root CA:
```

Step 8. In Tera Term, select [**File**]>[**Send file...**] to load the certificates for the AWS IoT device.
This information is available in the zip file you download during the device creation phase on ST Predictive Maintenance Dashboard.

Figure 28. Tera Term File menu



Step 9. Load the root CA.

```
Enter your root CA:
-----BEGIN CERTIFICATE-----
MKKDQTCCAimgAwKBAgKTBmyfz5m/jAo54vB4ikPmljZbyjANBgkphkiG9w0BAQsF
ADA5MQswCQYDVQQGEwWVUzEPMA0GA1UEChMGQW1hem9uMRkwFwYDVQQDExBBbWF6
b24gUm9vbCBDQSAxMB4XDTE1MDUyNjAwMDAwMFoXDTM4MDExNzAwMDAwMFowOTEL
MAkGA1UEBhMCVVMxDzANBgNVBAoTBkFtYXpvbjEZMBcGA1UEAxMQQW1hem9uKFWv
b3QgQ0EgMTCCASKwDQYWKoZKhvcNAQEBBQADggEPADCCAQoCggEBALW4gHHKeNXj
ca9HgFB0fW7Y14h29Wlo91ghYPl0hAEvrAKthtOgQ3pOspTQNroBvo3bSMgHFzZM
9O6KK8c+6zf1tRn4SWiw3te5bjgbYZ6k/oK2peVKVuRF4fn9tBb6bNpcmzU5L/pw
KFAGbHrQgLKm+a/sRxmPUDgH3KKHOVj4utWp+UhnMWbulHheb4mjUcAwhmahRWa6
VOujw5H5SNz/0egwLX0tbHA114gk957EWW67c4cX8jWGKLhD+rcbpsp08p8kDi1L
93FcXmn/6pUCyziKrlA4b9v7LWKbxcceVOF34GfKD5yHK9Y/QCB/KKDEgEw+OyQm
jgSubWrKpg0CAwEAAaNCMEAwDwYDVR0TAQH/BAUwAwEB/zAOBgNVHQ8BAf8EBAMC
AYYwHQYDVR0OBBYEFKQYzKU07LwMlWQuCFmcx7KQTgoKMA0GCSpGSKb3DQEBCwUA
A4KBAQCY8jbaQZChGsV2USggNiMOruYou6r4lK5KpDB/G/wkjUu0yKGX9rbxenDK
U5PMCCjjmCXPK6T53iHTfKUWrU6abTrCC2pWeHZERxhlbK1Bjjt/msv0tabQ1wUs
N+gDS63pYaACbvXy8MWy7Vu33PpUXHeeE6V/Up2V8viTO96LXFvKWlWbYK8U90vv
o/ufQWVtMVT8QtPHRh8jrbkPSHCa2XV4cbFyQzR1blbZwgWcWmApzyMZFo6KQ6XU
5MsK+yMRQ+hDKXWioalbXgjUkK642M4UwtBV8ob2xWNDb2ZhwLnoQbeXeGADbkpy
rpXRfboQnoZsG4p5WTP468SQvvG5
-----END CERTIFICATE-----
read: --->
-----BEGIN CERTIFICATE-----
MKKDQTCCAimgAwKBAgKTBmyfz5m/jAo54vB4ikPmljZbyjANBgkphkiG9w0BAQsF
ADA5MQswCQYDVQQGEwWVUzEPMA0GA1UEChMGQW1hem9uMRkwFwYDVQQDExBBbWF6
b24gUm9vbCBDQSAxMB4XDTE1MDUyNjAwMDAwMFoXDTM4MDExNzAwMDAwMFowOTEL
MAkGA1UEBhMCVVMxDzANBgNVBAoTBkFtYXpvbjEZMBcGA1UEAxMQQW1hem9uKFWv
b3QgQ0EgMTCCASKwDQYWKoZKhvcNAQEBBQADggEPADCCAQoCggEBALW4gHHKeNXj
ca9HgFB0fW7Y14h29Wlo91ghYPl0hAEvrAKthtOgQ3pOspTQNroBvo3bSMgHFzZM
9O6KK8c+6zf1tRn4SWiw3te5bjgbYZ6k/oK2peVKVuRF4fn9tBb6bNpcmzU5L/pw
KFAGbHrQgLKm+a/sRxmPUDgH3KKHOVj4utWp+UhnMWbulHheb4mjUcAwhmahRWa6
VOujw5H5SNz/0egwLX0tbHA114gk957EWW67c4cX8jWGKLhD+rcbpsp08p8kDi1L
93FcXmn/6pUCyziKrlA4b9v7LWKbxcceVOF34GfKD5yHK9Y/QCB/KKDEgEw+OyQm
jgSubWrKpg0CAwEAAaNCMEAwDwYDVR0TAQH/BAUwAwEB/zAOBgNVHQ8BAf8EBAMC
AYYwHQYDVR0OBBYEFKQYzKU07LwMlWQuCFmcx7KQTgoKMA0GCSpGSKb3DQEBCwUA
A4KBAQCY8jbaQZChGsV2USggNiMOruYou6r4lK5KpDB/G/wkjUu0yKGX9rbxenDK
U5PMCCjjmCXPK6T53iHTfKUWrU6abTrCC2pWeHZERxhlbK1Bjjt/msv0tabQ1wUs
N+gDS63pYaACbvXy8MWy7Vu33PpUXHeeE6V/Up2V8viTO96LXFvKWlWbYK8U90vv
o/ufQWVtMVT8QtPHRh8jrbkPSHCa2XV4cbFyQzR1blbZwgWcWmApzyMZFo6KQ6XU
5MsK+yMRQ+hDKXWioalbXgjUkK642M4UwtBV8ob2xWNDb2ZhwLnoQbeXeGADbkpy
rpXRfboQnoZsG4p5WTP468SQvvG5
-----END CERTIFICATE-----
<---
Enter your device certificate:
```

Step 10. Load the device certificate

```
Enter your device certificate:
-----BEGIN CERTIFICATE-----
MKKDWjCCAkKgAwKBAgKVAKPWpBtX6wziOY4z0pX19T7aU5owMA0GCSpGSKb3DQEB
CwUAME0xSzBWBgNVBAsMQkFtYXpvbiBXZWKgU2VybmljZXMgTz1BbWF6b24uY29t
KEluYy4gTD1TZWF0bGxlKFNUPVbhc2hpbmb0b24gQz1VUzAeFw0yMDAxMDgxNTU5
NDZaFw00OTEyMzEyMzU5NTlaMB4xHDAaBgNVBAMME0FXUyBWb1QgQ2VybGlmaWNh
bGUwggEiMA0GCSpGSKb3DQEBAQUAA4KBDwAwggEKAoKBAQClM1MNC651mpVE58v0
NL4E1Bj3U/uyEbPPNoOWxKNpbilBwGWODPUAuxobCEGosngjSEb9HUNnWYrmmb8C
n+WD0Xbfb9TWpLlmYEvwKwmvKuwU044LLtf/SDep6r9AabRHFfcB2p/HpMlYXYSM
263pm31Ykwlg6bM+vMAOLN8Op4EWWL2mV0WSr/vVmorVYUSiR8cmCwy83i6+KSrp
lD5Tm2PWmAcQXWvt+SFo1PMG39KfQUmMo4/mHZK8wu1yDPS6Qj504FKy0R9vpS9R
L0+pSuekXZ2Yo8vfF/TbfhiGxtsyVEA6GGnpyT5Y0jvu6AcTh+EbmnSREc/cOfZW
6nTRAgMBAAGjYDBeMB8GA1UbKwQYMBaAFKGrT790Mr50PFEctviicGkaTTsSMB0G
A1UbDgQWBBSKe3XF7KUTlz8ScmsgVR1Kftz2YTAMBgNVHRMBAf8EAjAAMA4GA1Ub
DwEB/wQEAwKHgDANBgkphkiG9w0BAQsFAAOCAQEAs/jWLhZrMpCyHG+lQWnrf7gK
1TRG6G+1DFfxzK6xCj+RFoNb9z617ncR7mFkpofKEY4XjVLpVDppEUmip/cBE7Cb
5crHSApEoO9vmpL/Sse/zRzkj5ui7C6Ycr609QLRAZRpb6/4MaeefzTLw1XCgLYz
Z0K4zL2rrp6FUv6WrX8h8b8+Zulm+V5KBGnNlP18gR1Z28f69htKoXne/mSr5NXY
XH9F0kPA/AUmD4mGZaUcsDRot0FOn5HMLTo2vf7tyciwTZxnYYPSiBi6AF5rCAeB
jPagM+lmhmNKeFcoen1m/HU5lLkKwK6/WMf24HPkK5avDpMo036U6NpY43YwCQ==
-----END CERTIFICATE-----
read: --->
-----BEGIN CERTIFICATE-----
MKKDWjCCAkKgAwKBAgKVAKPWpBtX6wziOY4z0pX19T7aU5owMA0GCSpGSKb3DQEB
CwUAME0xSzBWBgNVBAsMQkFtYXpvbiBXZWKgU2VybmljZXMgTz1BbWF6b24uY29t
KEluYy4gTD1TZWF0bGxlKFNUPVbhc2hpbmb0b24gQz1VUzAeFw0yMDAxMDgxNTU5
NDZaFw00OTEyMzEyMzU5NTlaMB4xHDAaBgNVBAMME0FXUyBWb1QgQ2VybGlmaWNh
bGUwggEiMA0GCSpGSKb3DQEBAQUAA4KBDwAwggEKAoKBAQClM1MNC651mpVE58v0
NL4E1Bj3U/uyEbPPNoOWxKNpbilBwGWODPUAuxobCEGosngjSEb9HUNnWYrmmb8C
n+WD0Xbfb9TWpLlmYEvwKwmvKuwU044LLtf/SDep6r9AabRHFfcB2p/HpMlYXYSM
263pm31Ykwlg6bM+vMAOLN8Op4EWWL2mV0WSr/vVmorVYUSiR8cmCwy83i6+KSrp
lD5Tm2PWmAcQXWvt+SFo1PMG39KfQUmMo4/mHZK8wu1yDPS6Qj504FKy0R9vpS9R
L0+pSuekXZ2Yo8vfF/TbfhiGxtsyVEA6GGnpyT5Y0jvu6AcTh+EbmnSREc/cOfZW
6nTRAgMBAAGjYDBeMB8GA1UbKwQYMBaAFKGrT790Mr50PFEctviicGkaTTsSMB0G
A1UbDgQWBBSKe3XF7KUTlz8ScmsgVR1Kftz2YTAMBgNVHRMBAf8EAjAAMA4GA1Ub
DwEB/wQEAwKHgDANBgkphkiG9w0BAQsFAAOCAQEAs/jWLhZrMpCyHG+lQWnrf7gK
1TRG6G+1DFfxzK6xCj+RFoNb9z617ncR7mFkpofKEY4XjVLpVDppEUmip/cBE7Cb
5crHSApEoO9vmpL/Sse/zRzkj5ui7C6Ycr609QLRAZRpb6/4MaeefzTLw1XCgLYz
Z0K4zL2rrp6FUv6WrX8h8b8+Zulm+V5KBGnNlP18gR1Z28f69htKoXne/mSr5NXY
XH9F0kPA/AUmD4mGZaUcsDRot0FOn5HMLTo2vf7tyciwTZxnYYPSiBi6AF5rCAeB
jPagM+lmhmNKeFcoen1m/HU5lLkKwK6/WMf24HPkK5avDpMo036U6NpY43YwCQ==
-----END CERTIFICATE-----
<---
Enter your device key:
```

Step 11. Load the device key.

```
Enter your device key:
-----BEGIN RSA PRIVATE KEY-----
MKKEowKBAAKCAQEApTNTDQuubZpVROfL9DS+BNQY91P7shGzzzaDicSDaW4pQcBl
jgz1ALsaGwhBpLW4K0hHfR1DZyWK5pnfAp/lg9F233fUyaS5ZmBL8CMWryLsFNOO
Cy7X/0g3pup/QGnURxX3Abpvx6TWWF2EjNut6Zt9WWMWYOnTPrzADizfDpuBCVi9
plbFkp/71ZpK1WFEokfHWgsMvN4uvikp6ZQ+U5tjyZgHEFyb7fkhaNTzBt/Sn0FW
jKOP5h2SvMLtcgz0ukK+bOBSstEfb6kvUS9PpkrnpF2bmKPL3xf0234YhsbbMlRA
Ohhp6sk+WNK77ugHE4fhHZp0kRHP3Dn2Sep00QKDAQABAoKBAHOMwrpNQSnhRic8
OtxFR+P4tr3KcHTNDQgTCU6Dtac49oKXKHGLfpNUS5482DA3WPEKzXglz8+F4vKW
DoO3c8KP8SW9m4ivPz7sfDErUMp/koG+t8v6p/pXeRiDueWEK8bVBkC1xb3O1UaW
ov0jazHLKWGjxxuScb+gWnXDzQFktHKVKyrXAPlVWf5c8VQrLQ6bS/rL3rcjHnfW
Qbpp1BGToPt7C7V9MhAchcQNCwnemDWacQ94G5BFW4eyN9bON9SSpjPnLzWfVbZ9
9kpiyQSWNxGXTy8o0f97Dr5Hhu7lr8FK2p54nLUyoAE9eNhRBBs2WBNHbOkozhAj
5H+bWkECgYEA2QFjmiKslvosNwcCbKNmsbkWb97atzAjNObmKt/wpWcYtfil5LN9
/zeOtyjGX5n602KcB8sVU7hpfgmR5Q0y6MEWeAnwwe0T354LDHCWQeLjitrnrXVa
M6mbg0GhlBPpHsKDTz/raXmH2yMyD/ygOrK3pt/Z3Y6ol2b+Fb+rew8CgYEAwuLS
ZHoOvM0b66fGjXobcuvN43i8kTi6K/SG2zQEiiM93KSPFuwk5EzlbE1a47bcuFuC
3Oi7HmBzlyx1NnNLFmmFKWTbiGQVSeKghafExXM8fyUO0aHEt+KgkDKKZ+inaoye
TMgHltZ/Xs89YP2SyVz3SThN8oFDHYKpiHiKkh8CgYEAp+kRPrRuuCu/hpyf48yD
p92EKyB/L/vWYie/tTEuMKYbcsKA6pOQPKipf0LHrDWjBWkGs2kKiYtW5UWWZ1t9
WugxEWTwe72MAR1zAx8Ytahv1KNpfKgvMYZu4W8p/UAiw7BS1kGpUCW/X2puU/xv
prs7o7YuB+bYwD5OK3K0ZzUCgYB/yC+BWBKvspD6/BARFZ5H1Nszpieh5WsQFjYS
WmWPnNnkATYbWort8ol/YW0WsFSoQMBmTmbafQ1tcuYL5L64HEoGGMx0+oKG5jDC
0gUQHgXtrAOyaipNE4ScZ7XOw9p532ewGnv3Z/8t0B6DpOAFDeLKbWOXTTAPemvk
onuRpwKBgC906TGbgFpaB0QOeZZVFmLbAmVW3Ws7p1Db/SbHrBzYp/teB5E3j3KH
xx5yL7NBuibHKvpmLKg2cZ1hAt8ZssOpXVG1b3gz3ZCHLWzjXl8H0EPovuTvToLE
OWc/KF7s9Oy070zEuno51/cyoDZuXE8H2LtWpYjxVohSKnXNxviW
-----END RSA PRIVATE KEY-----
read: --->
-----BEGIN RSA PRIVATE KEY-----
MKKEowKBAAKCAQEApTNTDQuubZpVROfL9DS+BNQY91P7shGzzzaDicSDaW4pQcBl
jgz1ALsaGwhBpLW4K0hHfR1DZyWK5pnfAp/lg9F233fUyaS5ZmBL8CMWryLsFNOO
Cy7X/0g3pup/QGnURxX3Abpvx6TWWF2EjNut6Zt9WWMWYOnTPrzADizfDpuBCVi9
plbFkp/71ZpK1WFEokfHWgsMvN4uvikp6ZQ+U5tjyZgHEFyb7fkhaNTzBt/Sn0FW
jKOP5h2SvMLtcgz0ukK+bOBSstEfb6kvUS9PpkrnpF2bmKPL3xf0234YhsbbMlRA
Ohhp6sk+WNK77ugHE4fhHZp0kRHP3Dn2Sep00QKDAQABAoKBAHOMwrpNQSnhRic8
OtxFR+P4tr3KcHTNDQgTCU6Dtac49oKXKHGLfpNUS5482DA3WPEKzXglz8+F4vKW
DoO3c8KP8SW9m4ivPz7sfDErUMp/koG+t8v6p/pXeRiDueWEK8bVBkC1xb3O1UaW
ov0jazHLKWGjxxuScb+gWnXDzQFktHKVKyrXAPlVWf5c8VQrLQ6bS/rL3rcjHnfW
Qbpp1BGToPt7C7V9MhAchcQNCwnemDWacQ94G5BFW4eyN9bON9SSpjPnLzWfVbZ9
9kpiyQSWNxGXTy8o0f97Dr5Hhu7lr8FK2p54nLUyoAE9eNhRBBs2WBNHbOkozhAj
5H+bWkECgYEA2QFjmiKslvosNwcCbKNmsbkWb97atzAjNObmKt/wpWcYtfil5LN9
/zeOtyjGX5n602KcB8sVU7hpfgmR5Q0y6MEWeAnwwe0T354LDHCWQeLjitrnrXVa
M6mbg0GhlBPpHsKDTz/raXmH2yMyD/ygOrK3pt/Z3Y6ol2b+Fb+rew8CgYEAwuLS
ZHoOvM0b66fGjXobcuvN43i8kTi6K/SG2zQEiiM93KSPFuwk5EzlbE1a47bcuFuC
3Oi7HmBzlyx1NnNLFmmFKWTbiGQVSeKghafExXM8fyUO0aHEt+KgkDKKZ+inaoye
TMgHltZ/Xs89YP2SyVz3SThN8oFDHYKpiHiKkh8CgYEAp+kRPrRuuCu/hpyf48yD
p92EKyB/L/vWYie/tTEuMKYbcsKA6pOQPKipf0LHrDWjBWkGs2kKiYtW5UWWZ1t9
WugxEWTwe72MAR1zAx8Ytahv1KNpfKgvMYZu4W8p/UAiw7BS1kGpUCW/X2puU/xv
prs7o7YuB+bYwD5OK3K0ZzUCgYB/yC+BWBKvspD6/BARFZ5H1Nszpieh5WsQFjYS
WmWPnNnkATYbWort8ol/YW0WsFSoQMBmTmbafQ1tcuYL5L64HEoGGMx0+oKG5jDC
0gUQHgXtrAOyaipNE4ScZ7XOw9p532ewGnv3Z/8t0B6DpOAFDeLKbWOXTTAPemvk
onuRpwKBgC906TGbgFpaB0QOeZZVFmLbAmVW3Ws7p1Db/SbHrBzYp/teB5E3j3KH
xx5yL7NBuibHKvpmLKg2cZ1hAt8ZssOpXVG1b3gz3ZCHLWzjXl8H0EPovuTvToLE
OWc/KF7s9Oy070zEuno51/cyoDZuXE8H2LtWpYjxVohSKnXNxviW
-----END RSA PRIVATE KEY-----
<---
Setting the RTC from the network time.
```

Step 12. As the AWS IoT section should already be configured, the sensors are automatically enabled and the MQTT connection runs.

```
Setting the RTC from the network time.
Connecting to www.gandi.net at ipaddress: 151.101.193.103
20001410 => X:\STSW-
STWINCELL\Middlewares\Third_Party\mbedTLS\library\ssl_tls.c:4643:
x509_verify_cert() returned -9984 (-0x2700)
Signal Level: -71 dBm
Configuring the RTC from Date: Tue, 18 Feb 2020 08:46:46 GMT
Initializing the Environmental Sensors ...
- Humidity sensor is ready.
- Pressure sensor is ready.
- Temperature sensor is ready.
Initializing the Inertial Sensor ...
- Accelero sensor is ready.
Initializing the Audio Sensor ...
- Audio sensor is ready.
Shadow Init ...
Shadow Connect ...
MQTT connection in progress:   Attempt 1/3 ...
Signal Level: -77 dBm
Signal Level: -71 dBm
Connected to a31pjrd6x4v4ba-ats.iot.eu-west-1.amazonaws.com:8883
```

Step 13. The shadow is automatically updated.

```
Update Shadow: {"state":{"reported":{"Device_Type":"STWIN","Features":
["Environmental","Inertial_TDM", "Inertial_FDM","Acoustic"],
"Firmware":"V1.0","Env_Time":50,"Ine_Time_TDM":50,"Ine_Time_FDM":50,"Aco_Time":50}},
"clientToken":"STWIN_BG96-0"}

Delta - EnvStreamingTime changed to 60

Delta - IneTdmStreamingTime changed to 10

Delta - IneFdmStreamingTime changed to 30

Delta - AcoStreamingTime changed to 10

Update Accepted!

Update Shadow: {"state":{"reported":{"Device_Type":"STWIN","Features":
["Environmental", "Inertial_TDM", "Inertial_FDM","Acoustic"],
"Firmware":"V1.0","Env_Time":60,"Ine_Time_TDM":10,"Ine_Time_FDM":30,"Aco_Time":10}},
"clientToken":"STWIN_BG96-5"}

Update Accepted!
```

Step 14. The data is now ready to begin uploading to the ST Predictive Maintenance Dashboard:

– Sound analysis in the frequency domain


```
Published to topic pm/STWIN_BG96/sense/acoustic:
{"Aco_FFT":[-72.86,-72.4,-74.61,-75.94,-73.730000000000009,-72.53,-73.92,-76.33,-
79.17,-78.39,-76.7,-77.540000000000009,-81.15,-83.790000000000009,-83.069999999999991
,-81.340000000000009,-80.680000000000009,-81.61,-83.659999999999991,-84.65,-
82.519999999999991,-79.94,-80.86,-84.02,-86.13,-84.57,-82.090000000000009,-81.87,-
83.81,-85.91,-85.98,-83.569999999999991,-83.180000000000009,-84.05,-86.38,-87.84,-
85.6,-84.04,-83.94,-86.05,-88.58,-86.1,-84.4,-84.39,-86.07,-88.99,-88.49,-87.03,-
86.13,-86.75,-90.33,-91.59,-88.65,-86.77,-87.42,-89.51,-91.94,-89.95,-87.98,-87.79,-
89.17,-91.79,-91.02,-89.47,-88.44,-89.17,-92.18,-92.43,-89.87,-88.81,-89.01,-90.93,-
92.67,-90.76,-88.88,-89.22,-90.34,-92.09,-91.16,-88.85,-87.76,-89.24,-91.44,-92.27,-
89.46,-87.97,-87.98,-90.41,-92.02,-90.08,-87.65,-87.17,-88.62,-91.62,-90.01,-87.43,-
87.11,-87.98,-91,-91.85,-89.81,-88.11,-87.93,-90.01,-92.55,-90.41,-87.91,-87.63,-
89.47,-92.61,-90.86,-88.08,-86.91,-86.94,-89.47,-91.04,-87.6,-85.73,-86.61,-89.85,-
92.77,-91.48,-89.86,-89.3,-90.99,-94.43,-94.38,-91.56,-90.99,-92.42,-94.72,-95.63,-
93.18,-91.67,-92.64,-94.93,-96.25,-94.85,-93.58,-93.67,-95.46,-97.43,-97.06,-95.83,-
94.68,-95.75,-97.49,-98.05,-96.08,-94.35,-94.76,-97.22,-99.18,-97.98,-96.46,-95.9,-
97.41,-99.48,-98.4,-96.13,-95.75,-97.11,-98.62,-96.64,-92.09,-90.13,-89.05,-88.49,-
92.4,-91.68,-89.38,-88.65,-91.03,-91.63,-90.38,-87.13,-86.48,-90.07,-94.93,-97.85,-
98.15,-96.42,-96.74,-98.34,-100.04,-100.96,-99.49,-99.21,-100.04,-100.57,-101.28,-
100.61,-99.65,-100.08,-100.85,-101.66,-101.35,-100.61,-100.83,-101.99,-
102.43000000000002,-102.41,-101.76,-101.36,-102.13,-103.5,-102.94,-101.59,-101,-
101.48,-103.48,-103.6,-102.09,-100.72,-101.05,-103.35,-105.01000000000002,-103.25,-
101.2,-101.22,-102.42,-105.01000000000002,-104.19,-101.6,-100.91,-101.66,-103.89,-
104.33,-102.36,-100.76,-100.72,-102.81999999999998,-104.12,-102.78,-101.54,-101.82,-
102.76000000000002,-103.64,-103.04,-101.3,-101.1,-102.17,-103.52,-103.68000000000002,
-101.61,-100.47,-100.81,-102.1,-103.81,-102.48,-100.74,-99.95,-101.35,-103.95,-
103.62,-101.71,-101.22,-102.47,-104.63,-104.89,-102.8,-101.8,-102.3,-
104.43000000000002,-106.04,-104.31999999999998,-101.2,-100.65,-103.36,-106.12,-
105.69,-104.02,-103.05,-103.96,-106.89,-107.94,-105.41,-104.05,-104.44,-106.7,-
108.06999999999998,-106.14,-104.22,-104.27,-106.03,-107.58,-107.39,-106.11,-105.46,-
106.28,-107.14,-107.63,-106.02,-104.95,-105.56,-106.35,-107.33,-106.61,-105.44,-
104.97,-106.09,-107.52,-107.52,-106.08,-105.14,-105.73999999999998,-107.17,-
107.73999999999998,-106.21,-105.06,-105.35,-107.2,-108.71,-107.23999999999998,-
105.31,-104.56999999999998,-105.48,-107.62,-106.96,-105.34,-104.3,-105.36,-108.38,-
108.89,-104.86,-102.42,-104.73999999999998,-107.81,-109.31,-107.76000000000002,-
105.35,-104.48,-104.86,-107.13,-106.79,-105.55,-105.36,-106.23,-108.31999999999998,-
109.13,-108.16,-107.1,-107.56,-108.44,-109.38,-108.81,-108,-107.7,-108.21,-108.84,-
108.36,-107.73999999999998,-106.65,-106.04,-108.28,-109.19,-108.5,-108.1,-
108.43000000000002,-108.98999999999998,-109.58,-109.19,-108.51000000000002,-108.38,-
109.12,-109.97,-109.48999999999998,-108.73,-108.16,-108.93000000000002,-
110.23999999999998,-110.27,-109.25,-108.23,-108.75,-110.18000000000002,-111.41,-
109.97,-108.77,-108.86,-109.95,-111.09,-110.77,-108.98,-108.51000000000002,-109.25,-
110.71,-110.97,-109.81,-108.61,-109.68000000000002,-110.78,-111.01000000000002,-
110.1,-109.37,-109.66,-110.53,-110.41,-110.19,-109.81,-109.45,-110.19,-110.35,-
110.65,-110.17,-109.76000000000002,-109.92,-110.71,-111.04,-110.19,-109.71,-109.9,-
110.73,-111.15,-110.76000000000002,-109.83,-109.39,-110.54,-111.37,-110.97,-110.05,-
109.16,-109.73999999999998,-111.39,-112.25,-111.28,-109.56,-109.16,-110.56,-112.56,-
112,-110.03,-109.25,-110.03,-112.13,-112.66,-110.7,-109.42,-109.76000000000002,-
111.37,-112.38,-111.23999999999998,-109.9,-109.53,-110.54,-111.51000000000002,-
111.51000000000002,-110.66,-109.81999999999998,-110.61,-111.05,-111.48,-111.16,-
110.5,-110.6,-110.76000000000002,-111.47,-111.02,-110.76000000000002,-110.89,-
111.09,-111.23,-111.35,-110.88,-110.63,-111.2,-111.08,-111.22,-111.13,-110.67,-
110.64,-111.11,-111.48999999999998,-111.69,-110.69,-110.15,-110.79,-112.46,-
112.38,-110.9,-110.03,-110.73999999999998,-112.6,-112.56,-111.28,-110.21,-110.25,-
111.98999999999998,-112.81,-111.66,-110.67,-110.31,-111.36,-112.37,-112.06,-111.28,-
110.7,-111.16,-111.54,-111.81999999999998,-111.39,-110.73,-111.22,-111.29,-111.53,-
111.6,-111.69,-111.31,-111.38,-111.06999999999998,-111.08,-111.47],
"Aco_FS":192000,"Aco_SZE":1024}
```


– Vibration analysis in the time domain


```
Published to topic pm/STWIN_BG96/sense/inertial_tdm:
{"RMS_Speed": [0.42,0.41,0.11], "Peak_Acceleration": [2.57,3.30,8.12]}
```

– Vibration analysis in the frequency domain


```
Published to topic pm/STWIN_BG96/sense/inertial_fdm:
{"Ine_FFT": [[0.00,0.00,0.00,0.00],[25.96,0.00,0.00,0.01],[51.91,0.01,0.00,0.01],
[77.87,0.01,0.00,0.01],
[103.83,0.01,0.01,0.01],[129.79,0.01,0.01,0.01],[155.74,0.01,0.01,0.01],
[181.70,0.01,0.01,0.01],
[207.66,0.01,0.01,0.01],[233.61,0.01,0.01,0.01],[259.57,0.01,0.01,0.01],
[285.53,0.01,0.01,0.01],
[311.48,0.01,0.01,0.01],[337.44,0.01,0.01,0.01],[363.40,0.01,0.01,0.01],
[389.36,0.01,0.01,0.01],
[415.31,0.01,0.01,0.01],[441.27,0.01,0.01,0.01],[467.23,0.01,0.01,0.01],
[493.18,0.01,0.01,0.01],
[519.14,0.01,0.01,0.01],[545.10,0.01,0.01,0.01],[571.05,0.01,0.01,0.01],
[597.01,0.01,0.01,0.01],
[622.97,0.01,0.01,0.01],[648.93,0.01,0.01,0.01],[674.88,0.01,0.01,0.01],
[700.84,0.01,0.01,0.01],
[726.80,0.01,0.01,0.01],[752.75,0.01,0.01,0.01],[778.71,0.01,0.01,0.01],
[804.67,0.01,0.01,0.01],
[830.63,0.01,0.01,0.01],[856.58,0.01,0.01,0.01],[882.54,0.01,0.01,0.01],
[908.50,0.01,0.01,0.01],
[934.45,0.01,0.01,0.01],[960.41,0.01,0.01,0.01],[986.37,0.01,0.01,0.01],
[1012.32,0.01,0.01,0.01],
[1038.28,0.01,0.01,0.01],[1064.24,0.01,0.01,0.01],[1090.20,0.01,0.01,0.01],
[1116.15,0.01,0.01,0.01],
[1142.11,0.01,0.01,0.01],[1168.07,0.01,0.01,0.01],[1194.02,0.01,0.01,0.01],
[1219.98,0.01,0.01,0.01],
[1245.94,0.01,0.01,0.01],[1271.89,0.01,0.01,0.01],[1297.85,0.01,0.01,0.01],
[1323.81,0.01,0.01,0.01],
[1349.77,0.01,0.01,0.01],[1375.72,0.01,0.01,0.01],[1401.68,0.01,0.01,0.01],
[1427.64,0.01,0.01,0.01],
[1453.59,0.01,0.00,0.01],[1479.55,0.01,0.01,0.01],[1505.51,0.01,0.01,0.01],
[1531.46,0.01,0.01,0.01],
[1557.42,0.01,0.01,0.01],[1583.38,0.01,0.01,0.01],[1609.34,0.01,0.01,0.01],
[1635.29,0.01,0.00,0.01],
[1661.25,0.01,0.01,0.01],[1687.21,0.01,0.01,0.01],[1713.16,0.01,0.01,0.01],
[1739.12,0.01,0.01,0.01],
[1765.08,0.01,0.01,0.01],[1791.04,0.01,0.01,0.01],[1816.99,0.01,0.01,0.01],
[1842.95,0.01,0.01,0.01],
[1868.91,0.01,0.01,0.01],[1894.86,0.01,0.01,0.01],[1920.82,0.01,0.01,0.01],
[1946.78,0.01,0.01,0.01],
[1972.73,0.01,0.01,0.01],[1998.69,0.01,0.01,0.01],[2024.65,0.01,0.01,0.01],
[2050.61,0.01,0.01,0.01],
[2076.56,0.01,0.01,0.01],[2102.52,0.01,0.00,0.01],[2128.48,0.01,0.00,0.01],
[2154.43,0.01,0.01,0.01],
[2180.39,0.01,0.01,0.01],[2206.35,0.01,0.01,0.01],[2232.30,0.01,0.01,0.01],
[2258.26,0.01,0.01,0.01],
[2284.22,0.01,0.01,0.01],[2310.18,0.01,0.01,0.01],[2336.13,0.01,0.01,0.01],
[2362.09,0.01,0.01,0.01],
[2388.05,0.01,0.01,0.01],[2414.00,0.01,0.00,0.01],[2439.96,0.01,0.00,0.01],
[2465.92,0.01,0.01,0.01],
[2491.88,0.01,0.01,0.01],[2517.83,0.01,0.01,0.01],[2543.79,0.01,0.01,0.01],
[2569.75,0.01,0.01,0.01],
[2595.70,0.01,0.01,0.01],[2621.66,0.01,0.01,0.01],[2647.62,0.01,0.01,0.01],
[2673.57,0.01,0.01,0.01],
[2699.53,0.01,0.01,0.01],[2725.49,0.01,0.01,0.01],[2751.45,0.01,0.01,0.01],
[2777.40,0.01,0.00,0.01],
[2803.36,0.01,0.00,0.01],[2829.32,0.01,0.01,0.01],[2855.27,0.01,0.00,0.01],
[2881.23,0.01,0.00,0.01],
[2907.19,0.01,0.00,0.01],[2933.14,0.01,0.01,0.01],[2959.10,0.01,0.01,0.01],
[2985.06,0.01,0.01,0.01],
[3011.02,0.01,0.00,0.01],[3036.97,0.01,0.00,0.01],[3062.93,0.01,0.00,0.01],
[3088.89,0.01,0.00,0.01],
[3114.84,0.01,0.00,0.01],[3140.80,0.01,0.00,0.01],[3166.76,0.01,0.00,0.01],
[3192.71,0.01,0.00,0.01],
[3218.67,0.01,0.00,0.01],[3244.63,0.01,0.01,0.01],[3270.59,0.01,0.01,0.01],
[3296.54,0.01,0.01,0.01],
[3322.50,0.01,0.01,0.01],[3348.46,0.01,0.01,0.01],[3374.41,0.01,0.01,0.01],
```

```
[3400.37,0.01,0.00,0.01],
[3426.33,0.01,0.00,0.01],[3452.29,0.01,0.01,0.01],[3478.24,0.01,0.01,0.01],
[3504.20,0.01,0.00,0.01],
[3530.16,0.01,0.00,0.01],[3556.11,0.01,0.00,0.01],[3582.07,0.01,0.00,0.01],
[3608.03,0.01,0.01,0.01],
[3633.98,0.01,0.01,0.01],[3659.94,0.01,0.01,0.01],[3685.90,0.01,0.01,0.01],
[3711.86,0.01,0.00,0.01],
[3737.81,0.01,0.00,0.01],[3763.77,0.01,0.00,0.01],[3789.73,0.01,0.00,0.01],
[3815.68,0.01,0.00,0.01],
[3841.64,0.01,0.00,0.01],[3867.60,0.01,0.00,0.01],[3893.55,0.01,0.00,0.01],
[3919.51,0.01,0.00,0.01],
[3945.47,0.01,0.00,0.01],[3971.43,0.01,0.01,0.01],[3997.38,0.01,0.01,0.01],
[4023.34,0.01,0.00,0.01],
[4049.30,0.01,0.00,0.01],[4075.25,0.01,0.00,0.01],[4101.21,0.01,0.00,0.01],
[4127.17,0.01,0.00,0.01],
[4153.13,0.01,0.01,0.01],[4179.08,0.01,0.00,0.01],[4205.04,0.01,0.00,0.01],
[4231.00,0.01,0.00,0.01],
[4256.95,0.01,0.00,0.01],[4282.91,0.01,0.01,0.01],[4308.87,0.01,0.01,0.01],
[4334.82,0.01,0.00,0.01],
[4360.78,0.01,0.01,0.01],[4386.74,0.01,0.01,0.01],[4412.70,0.01,0.00,0.01],
[4438.65,0.01,0.00,0.01],
[4464.61,0.01,0.01,0.01],[4490.57,0.01,0.00,0.01],[4516.52,0.01,0.00,0.01],
[4542.48,0.01,0.00,0.01],
[4568.44,0.01,0.01,0.01],[4594.39,0.01,0.01,0.01],[4620.35,0.01,0.01,0.01],
[4646.31,0.01,0.01,0.01],
[4672.27,0.01,0.01,0.01],[4698.22,0.01,0.00,0.01],[4724.18,0.01,0.01,0.01],
[4750.14,0.01,0.01,0.01],
[4776.09,0.01,0.01,0.01],[4802.05,0.01,0.00,0.01],[4828.01,0.01,0.01,0.01],
[4853.96,0.01,0.00,0.01],
[4879.92,0.01,0.00,0.01],[4905.88,0.01,0.01,0.01],[4931.84,0.01,0.01,0.01],
[4957.79,0.01,0.01,0.01]]}
```


– Environmental humidity, pressure and temperature values


```
Published to topic pm/STWIN_BG96/sense/environmental:
{"Humidity": 34.37, "Pressure": 1028.54, "Temperature": 30.28}
```


Step 15. Confirm that the data has been uploaded onto the ST Predictive Maintenance Dashboard.

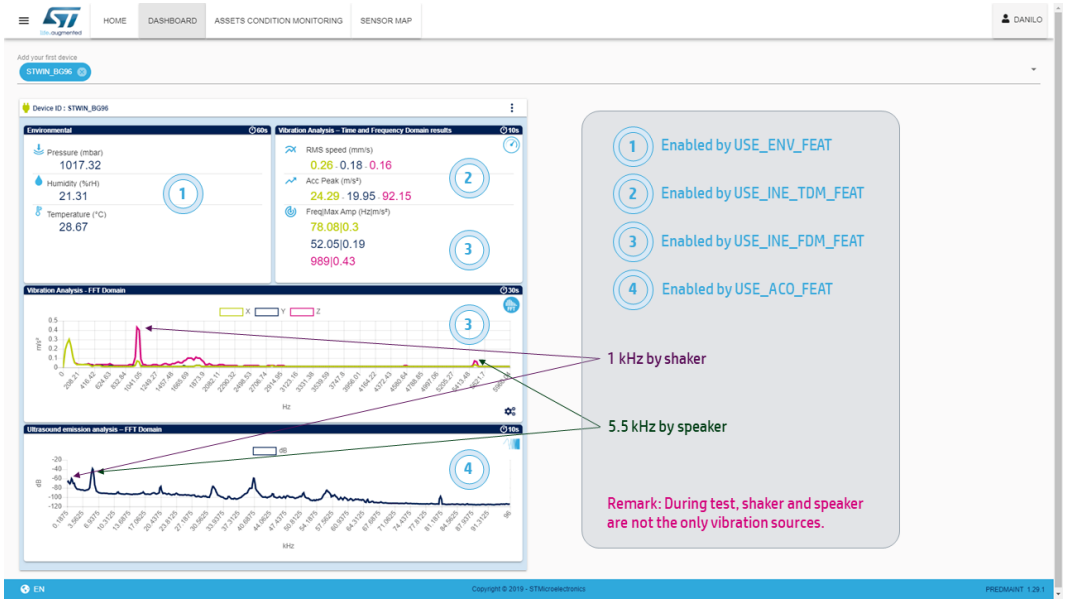
When all the features are enabled, the dashboard should display the following information:

– Environmental parameters
  - Pressure: Using LPS22HH, high-performance MEMS nano pressure sensor, into the range 260÷1260 hPa.
  - Humidity and Temperature: Using HTS221, capacitive digital sensor for relative humidity, into the range 0÷100 % rH, and temperature, into the range -40÷120 °C.

– Vibration preprocessed data
  - Peaks on time and frequency domain and FFT: Using IIS3DWB, 6 kHz bandwidth, low-noise, 3-axis digital vibration sensor with user-selectable full-scale (±2, ±4. ±8 and ±16 g) and 3kB FIFO.

– Ultrasound preprocessed data
  - FFT: Using MP23ABS1, 80 kHz bandwidth, high-performance MEMS audio sensor with an acoustic overload point of 130 dBSPL.

Figure 29. DSH-PREDMNT data for sensor node subject to 1 kHz vibration and 5.5 kHz acoustic waves



RELATED LINKS

5 How to activate the ST Predictive Maintenance Dashboard on page 20

7 Optimizing modem scanning and connection times on page 38

6.2 SIMs used in testing

The APN information that you load through the terminal window during the application setup relates to the cellular network operator and the protocol used by the SIM.

The application was successfully tested using the following mobile network operators (MNO)/mobile virtual network operators (MVNO) and SIMs:

- Protocol: LTE Cat M1:
  - Provider (France): Orange (MNO), Truphone (MVNO)
- Protocol: LTE Cat NB1
  - Provider (Italy): TIM (MNO)
  - Provider (France): SFR (MNO)

6.3 Parameters stored in flash

The cellular network configuration and AWS IoT certificates entered via the terminal console are written into separate flash memory locations on the STEVAL-STWINKT1B sensor node STM32 microcontroller. This ensures that the information is not lost when the firmware is updated and the node retains its portability with no further connection with a PC required, unless you need to update the parameters when, for example, you want to change the SIM.

Note: During firmware updates, you will be prompted in the terminal window to confirm the stored parameters by pressing the user button on the sensor node within a certain period.

The position of the certificate data in the flash is defined in the `iot_flash_config.c` code with keywords like `__ICFEDIT_region_FIXED_LOC_start__` for IAR and `UNINIT_FIXED_LOC` for Keil and GNU compilers. These keywords are defined in ILINK configuration files (ifc) for IAR, scatter files (sct) for Keil, or load files (ld) for GNU compilers.

7 Optimizing modem scanning and connection times

As the BG96 modem can scan all possible bands available to the modem, it may be useful to restrict modem scanning to bands that are compatible with the device location and radio environment.

When no M1 or NB1 network is available, the 2G fallback connection can take several minutes. In this case, it is worth restricting the possible protocols (2G only, or M1 and 2G) as well as the bands the modem should scan by programming the BG96 flash with the correct sequence of AT commands.

The above can be achieved using X-CUBE-CELLULAR, which consists of a set of libraries and application examples for STM32L4 Series MCUs acting as hosts for cellular connectivity applications.

An alternative method is to send the AT command directly to the modem through its USB AT port. This method requires the Quectel LTE&5G Windows USB driver, which can be downloaded from the Quectel website.

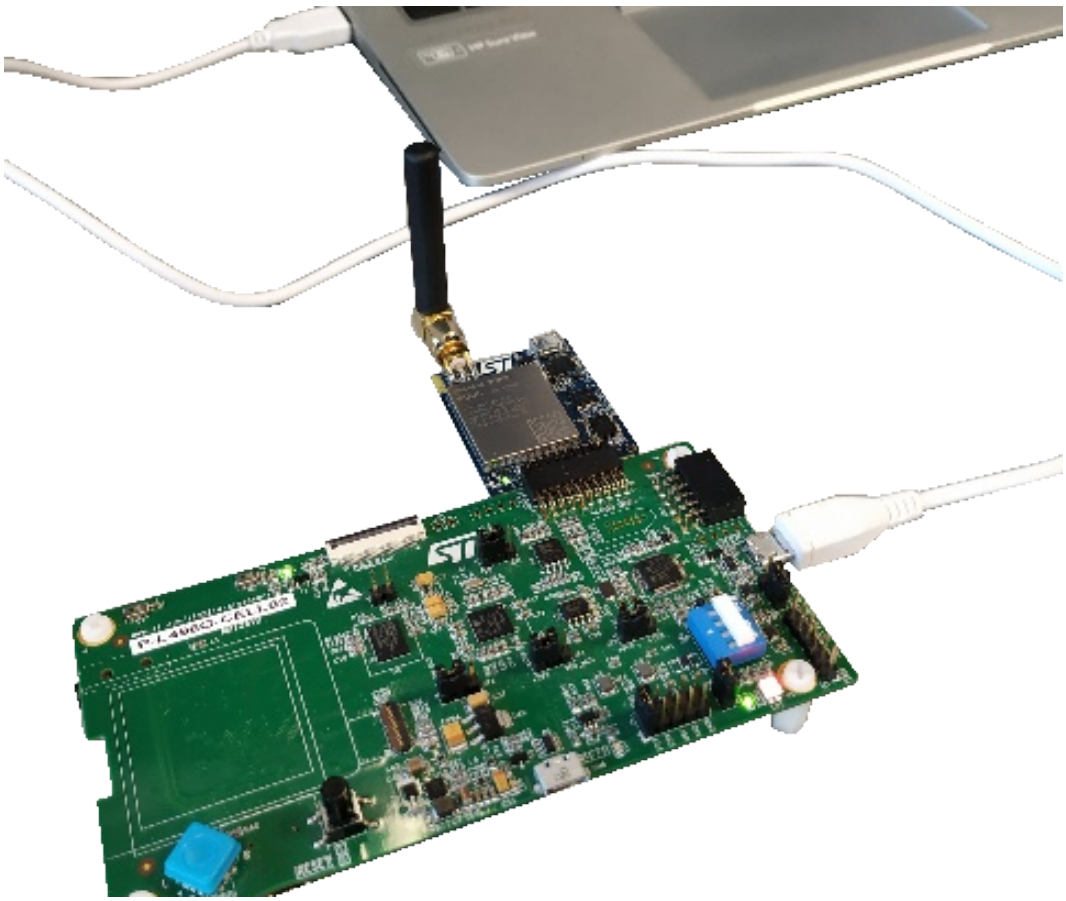
7.1 Program the BG96 modem using X-CUBE-CELLULAR software

Step 1. Download and unzip the X-CUBE-CELLULAR package to a suitable folder on your PC.
This example uses V5.0.0.

Step 2. Plug the BG96 cellular expansion board into the STMod+ connector on the P-L496G-CELL02 Discovery board with microcontroller.

Step 3. Connect the Discovery board to your PC via micro USB cable.

Figure 30. P-L496G-CELL02 kit connected to PC



Step 4. Run Tera Term, select the appropriate COM port, and set the parameters shown below:

Terminal

- [**New line**]
  - [**Receive**]: CR
  - [**Transmit**]: CR
- [**Local Echo**] selected

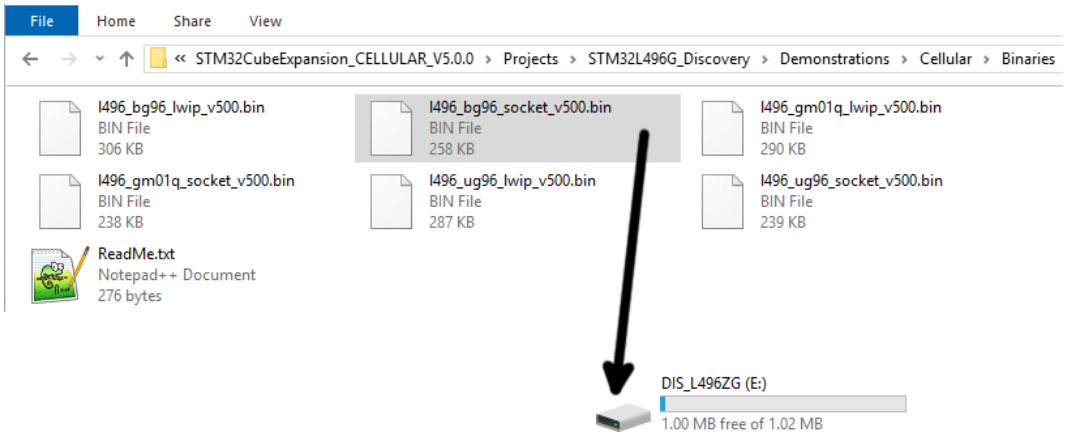
Serial

- [**Baud rate**]: 115200
- [**Data**]: 8 bit
- [**Parity**]: none
- [**Stop**]: 1 bit
- [**Flow control**]: none
- [**Transmit delay**]: 10 ms each

Step 5. Drag the following pre-built binary file onto the drive representing the P-L496G-CELL02 device:

STM32CubeExpansion_CELLULAR_V5.0.0\Projects\STM32L496G_Discovery\Demonstrations\Cellular\Binaries\ l496_bg96_socket_v500.bin

Figure 31. Load firmware onto P-L496G-CELL02



Step 6. Observe the terminal console while the X-CUBE-CELLULAR firmware running.

```
BG96 UART config: BaudRate=115200 / HW flow ctrl=1
============================
    X-CUBE-CELLULAR
    Version: V5.0.0
============================
Select the application to run:
1: Setup configuration Menu
2: Modem power on (without application)
3: FAQ display
Or type any key to start
2-----> State : CST_MODEM_INIT_STATE <-----
********** CST_power_on_only_modem_mngt ********
SysCtrl_BG96:Waiting 5500 millisec for modem running...
SysCtrl_BG96:...done
```

Step 7. Select choice [2] from the menu to be send the commands to setup the modem.

Step 8. Observe the cellular technology (LTE Cat M, NB-IoT, GSM) and the bands used from the trace at boot time, illustrated in the example below:

The scan ranking below begins with the B13 band in M1, followed by all the GSM bands, and ends with B4 band in NB1.

```
BG96:>>>>> BG96 mode and bands configuration <<<<<
BG96:LTE Cat.M1 band active (scan rank = 1)
BG96:Cat.M1 BANDS config = 0x01000
BG96:CatM1_B13
BG96:GSM band active (scan rank = 2)
BG96:GSM BANDS config = 0xf
BG96:GSM_900
BG96:GSM_1800
BG96:GSM_850
BG96:GSM_1900
BG96:LTE Cat.NB1 band active (scan rank = 3)
BG96:Cat.NB1 BANDS config = 0x08
BG96:CatNB1_B4
BG96:>>>>> ............................... <<<<<
```

Step 9. Hit [**Enter**] on your keyboard and type the following commands after the prompt:

```
modem config iotopmode NB1
modem config nwscanmode AUTO
modem config gsmband any
modem config m1band any
modem config nb1band any
modem config scanseq NB1_M1_GSM
modem config send
```

Step 10. Disconnect the P-L496G-CELL02 Discovery board and detach the cellular expansion board with BG96 modem.

Step 11. Connect the cellular expansion board onto the STEVAL-STWINKT1B sensor node and run the STSW-STWINCELL demo software.

RELATED LINKS

The X-CUBE-CELLULAR web folder has several resources, including a user manual.

visit the Quectel website for more information on the BG96 module

7.2 Program BG96 sending AT commands

Before you begin, you must request the Quectel LTE and 5G USB driver for Windows in the customer service and support area at the Quectel website.

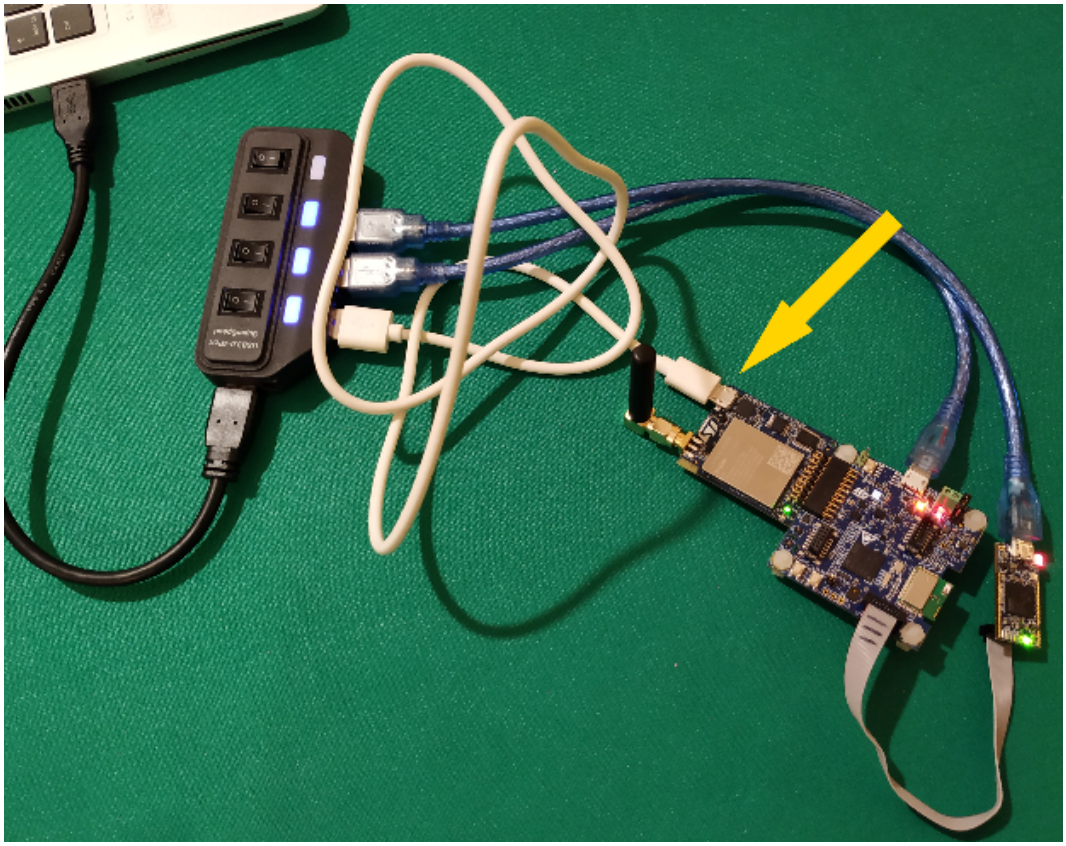
Step 1. Downloaded and install the driver on a suitable Windows PC

Step 2. Connect the BG96 cellular expansion board to the STEVAL-STWINKT1B node powered via USB or battery

Step 3. Establish a programming connection between your PC and the sensor node via the STLINK-V3MINI debugger

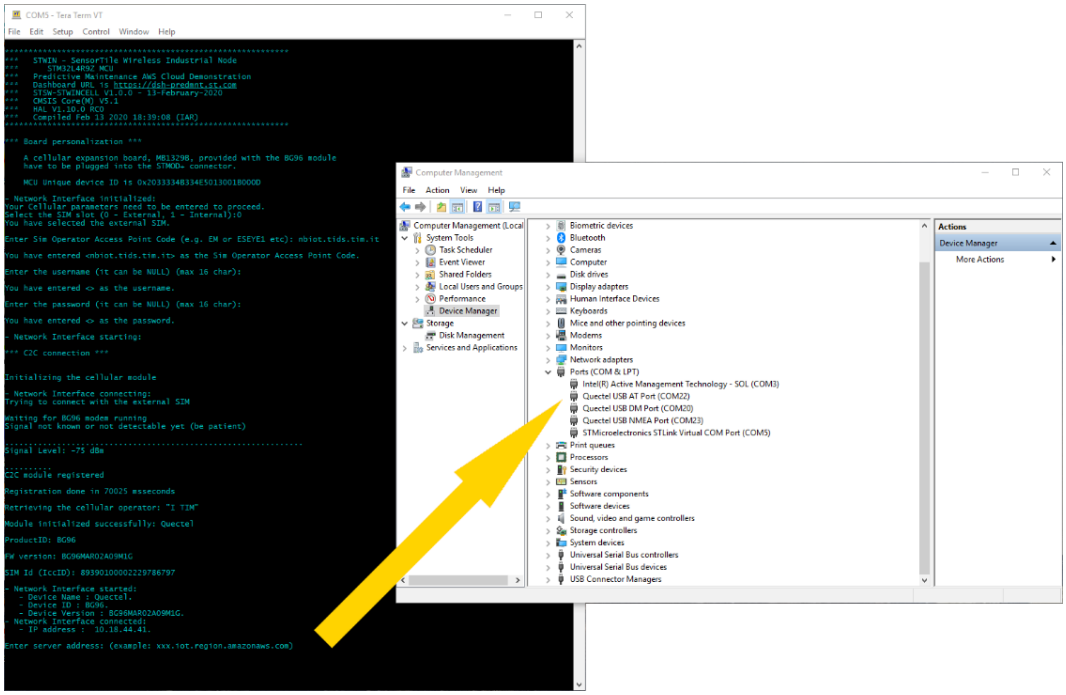
Step 4. Connect another USB cable from your PC to the micro USB socket on the BG96 cellular expansion board

Figure 32. STEVAL-STWINKT1B with BG96 cellular expansion board connected to PC



Step 5. Run the demonstration application until you are prompted for the IoT Endpoint

Figure 33. Prepare Quectel BG96 to expose USB AT Port



Step 6. Start a new instance of Tera Term, select the appropriate COM port and set the parameters shown below:

Terminal

- [**New line**]
  - [**Receive**]: AUTO
  - [**Transmit**]: CR
- [**Local Echo**] selected

Serial

- [**Port**]: Quectel USB AT Port assigned by OS (see Figure 33)
- [**Baud rate**]: 115200
- [**Data**]: 8 bit
- [**Parity**]: none
- [**Stop**]: 1 bit
- [**Flow control**]: none
- [**Transmit delay**]: 10 ms each

Step 7. Use the following Network Searching AT commands to configure the modem to scan for NB-IoT only.
You can modify the code to limit scanning to other networks and bands according the document "BG96 Network Searching Scheme Introduction".

```
at

OK
AT+QCFG="nwscanseq",030201,1

OK
AT+QCFG="nwscanmode",3,1

OK
AT+QCFG="iotopmode",1,1

OK
AT+QCFG="band",0000000F,400A0E189F,A0E189F,1

OK AT+QCFG="nwscanseq" +QCFG: "nwscanseq",030201

OK
AT+QCFG="nwscanmode" +QCFG: "nwscanmode",3

OK
AT+QCFG="iotopmode" +QCFG: "iotopmode",1

OK
AT+QCFG="band" +QCFG: "band",0xf,0x400a0e189f,0xa0e189f

OK
AT+QNWINFO

+QNWINFO: "CAT-NB1","22201","LTE BAND 20",6253

OK
```

RELATED LINKS

visit the Quectel website to request the document: "BG96 Network Searching Scheme Introduction"

8 Acronyms and abbreviations

Table 1. List of acronyms

Acronym	Description
API	Application Programming Interface
APN	Access Point Name
AWS	Amazon Web Services
BSP	Board Support Package
CA	Certificate Authority
CMSIS	Cortex Microcontroller Software Interface Standard
DSH-PREDMNT	ST Predictive Maintenance Dashboard
EDGE	Enhanced Data rates for GSM Evolution also known as EGPRS
EGPRS	Enhanced General Packet Radio Service
eMTC	Enhanced Machine Type Communication
HAL	Hardware abstraction layer
HSPA	High Speed Packet Access
IDE	Integrated Development Environment
IoT	Internet of Things
JSON	JavaScript Object Notation
LPWAN	Low Power Wide Area Network
LTE	Long-Term Evolution
LTE-M	Or LTE-MTC (LTE-Machine Type Communication), which includes eMTC
LTE Cat M1	eMTC category M1
LTE Cat NB1	NB-IoT category NB1
MNO	Mobile Network Operator
MVNO	Mobile Virtual Network Operator
MQTT	MQ Telemetry Transport or Message Queue Telemetry Transport
NB-IoT	Narrowband Internet of Things
PEM	Privacy Enhanced Mail
PRB	Physcial Resource Blocks
RAT	Radio access technology
RSA	Rivest–Shamir–Adleman
RTOS	Real-time operating system
SDK	Software Development Kit
SIM	Subscriber Identity Module
TLS	Transport Layer Security
UMTS	Universal Mobile Telecommunications System
3FF	3rd Form Factor
3GPP	3rd Generation Partnership Project

Revision history

Table 2. **Document revision history**

Date	Version	Changes
23-Mar-2020	1	Initial release.
16-Mar-2021	2	Added STEVAL-STMODLTE compatibility information.

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