Getting started with the X-CUBE-CELLULAR cellular connectivity Expansion Package for STM32Cube

Introduction

The X-CUBE-CELLULAR Expansion Package enables connectivity over cellular networks. The network access technology depends on the cellular modem used. It can be 2G/3G as well as LTE Cat M1 or NB-IoT.

This user manual provides:

- A brief content description of the X-CUBE-CELLULAR Expansion Package for STM32Cube
- Instructions to start the hardware composed of a board based on an STM32 microcontroller associated with a modem, and to exchange data through a cellular network by means of X-CUBE-CELLULAR firmware

1 Acronyms

Table 1 presents the definitions of the acronyms that are relevant for a better contextual understanding of this document.

Table 1. Acronyms

Acronym	Definition
API	Application programming interface
APN	Access point name
C2C	Cellular to cloud
CLI	Command-line interface
DB	Data brief (STMicroelectronics document type)
eSIM	Embedded SIM
FAQ	Frequently asked questions
FW	Firmware
HTTP	Hypertext transfer protocol
HW	Hardware
ICC	International circuit card
ICCID	International circuit card identifier
IDE	Integrated development environment
IMSI	International mobile subscriber identity
IP	Internet protocol
MCU	Microcontroller unit
MQTT	Message queuing telemetry transport
MVNO	Mobile virtual network operator
PC	Personal computer
RN	Release note (STMicroelectronics document type)
SIM	Subscriber identity module
UM	User manual (STMicroelectronics document type)

The X-CUBE-CELLULAR Expansion Package runs on the STM32L4 32-bit microcontrollers based on the Arm® Cortex®-M4 processor.

Note: Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

2 Overview of available documents

Table 2 lists the main documents useful for getting X-CUBE-CELLULAR started.

Table 2. References

ID	Description
[1]	Release note: The main RN is available at the root of the X-CUBE-CELLULAR Expansion Package. The main RN provides a link to the *Cellular RN*, which contains all information about the current delivery(1).
[2]	Data brief: *Cellular connectivity software expansion for STM32Cube* data brief (DB3582). The DB summarizes X-CUBE-CELLULAR features and presents the main license terms associated with the Expansion Package. It is available from STMicroelectronics web site at *www.st.com*.
[3]	User manual: *Getting started with the X-CUBE-CELLULAR cellular connectivity Expansion Package for STM32Cube* user manual (UM2426). The UM provides the detailed information needed to use X-CUBE-CELLULAR and adapt it to users' needs. It is available from STMicroelectronics web site at *www.st.com*.

1. *Read carefully the associated RNs as they provide important information about the "Cellular" delivery. The "Cellular framework RN" contains a FAQ, which is regularly updated.*

Note: An STMicroelectronics video is available on YouTube™ to help users start with their cellular-to-cloud kits. Reach this video through C2C pages on www.st.com or directly at https://youtu.be/b2-37F7wcaI on YouTube™.

3 Hardware and firmware setup

3.1 Connect hardware

To start using X-CUBE-CELLULAR, the user needs:

- A PC
- A Type-A to Micro-B USB cable
- An STM32L4-based master hardware combined to, or associated with a cellular modem (refer to [2] or [3] for possible solutions)

The PC is used to power HW, program FW, and display STM32 FW traces and results onto a serial terminal.

The ST-LINK USB driver, available as STSW-LINK009 on STMicroelectronics web site at *www.st.com*, is mandatory and must be installed on the PC. It is needed to program FW onto the STM32 microcontroller.

Follow the next five steps to connect the HW:

1. If the STM32 microcontroller and modem are on separate boards, connect these boards together.
   Note: On the modem board, the modem module is on the upper side.
2. Connect the antenna.
3. All the boards compatible with X-CUBE-CELLULAR provide a SIM slot, which makes it possible to use a plastic SIM instead of an eSIM. If this option is selected, insert the SIM card.
4. Connect the *STLink* port of the STM32 board with the PC by means of the USB cable.
5. See that a new drive corresponding to the STM32 board is available on the PC, resulting from the previous installation of the ST-LINK USB driver.

3.2 Activate the eSIM (optional)

This section applies only to the P-L496G-CELL01 and P-L496G-CELL02 among the HW compatible with X-CUBE-CELLULAR. The other compatible pieces of HW must be used with a plastic SIM.

The P-L496G-CELL01 and P-L496G-CELL02 Discovery packs contain an STMod+ board that embeds an eSIM provisioned with EMnify (MVNO) prepaid data plan profile. Once activated, it allows the user a free amount of 15 Mbytes of data for 90 days. When the data is used or the 90-day period is over, the user can contact EMnify to upgrade his plan. The user can monitor his data consumption and registration status on the EMnify portal.

The original binary firmware programmed during the factory process displays information, such as URL and voucher, required for user registration. The user must connect to the provided URL with a browser, create an account, and enter the voucher. A new HW is added to his account (more than one HW can be registered to the same account, in this case the user has a HW list). Once the voucher is entered, the user must select the EMnify button (click on the EMnify logo) to activate the eSIM provisioned with EMnify profile: the BIC information related to the eSIM is already pre-filled, the eSIM is activated and allows the connection to cellular networks.

To register a new eSIM on his existing account, the user is requested to go to the EMnify account management and activate the additional eSIM.

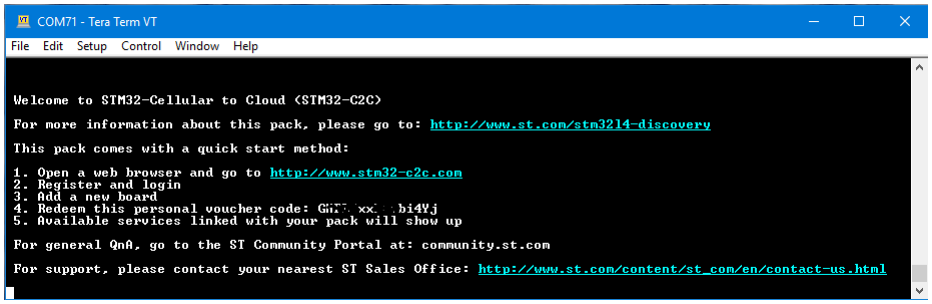
To use an EMnify eSIM, perform the following by means of the menu:

- Select [**eSIM**] (plastic SIM is the default value)
- Set [**APN**] to `EM`
- Keep all other parameters to their default values

Caution: In case the user HW is P-L496G-CELL01 or P-L496G-CELL02, programming a new FW erases factory FW, making the voucher required for registration unavailable and eSIM activation impossible. It is possible to recover the voucher by re-programming factory FW or using an AT command (refer to FAQ in [1] and to the STMicroelectronics video presented in Section 2 Overview of available documents).

Figure 1 shows cellular-to-cloud factory FW.

Figure 1. Cellular-to-cloud factory firmware display



To see the voucher, the user simply needs to install and configure a serial terminal on his PC. A serial terminal is used to output traces and menu onto the PC. Tera Term is the tool used for that purpose in the framework of the current document as well as in [3]. Proceed as follows for configuring the serial terminal:

1. Install the Tera Term software on the PC
2. Check that the STM32 board is connected to the PC through the USB cable
3. Start Tera Term and select the proper connection (featuring the *STMicroelectronics* name)
4. Set the parameters
   a. Terminal
      - [**New line**]
        - [**Receive**]: `CR`
        - [**Transmit**]: `CR`
      - [**Local echo**] selected
   b. Serial
      - [**Baud rate**]: `9600`
      - [**Data**]: `8 bit`
      - [**Parity**]: `none`
      - [**Stop**]: `1 bit`
      - [**Flow control**]: `none`
      - [**Transmit delay**]: `10 ms` each

Connect the board to the PC and press the black reset button of the board. A trace appears with the instructions and voucher information.

3.3 Program firmware into the STM32 microcontroller

This section explains how to select binary firmware and program it into the STM32 microcontroller.

Binary FW is delivered as part of the X-CUBE-CELLULAR Expansion Package, for each supported IDE: STM32CubeIDE, IAR™ or Keil®.

For example, for the 32L496GDISCOVERY, the binaires are located in `Projects\STM32L496G_Discovery\Demonstrations\Cellular\Binaries\<XXX>\`, where `<XXX>` indicates the IDE:

- `<XXX>` = `cubeide`: STM32CubeIDE
- `<XXX>` = `iar`: IAR™
- `<XXX>` = `keil`: Keil®

The IP mode (LwIP or modem-socket) used in the binary is part of the file name. See for instance two binaries produced with the IAR™ IDE for the BG96 modem:

- `iar_bg96_lwip_v300.bin` for the LwIP mode
- `iar_bg96_socket_v300.bin` for the modem-socket mode

The string `wot` in a file name means 'without trace'.

Note: There are two configuration modes concerning the location of the IP stack:

- *Either the IP stack runs on the STM32 microcontroller (LwIP mode)*
- *Or the IP stack used is located in the modem (modem-socket mode)*

Only the LwIP mode is available when the modem does not include an IP stack or no AT command is available to expose the socket interface.

The main interests of the modem-socket mode is to reduce the STM32 memory footprint and make STM32 exchanges with the modem simpler. The main drawback of the modem-socket mode is lower performance.

Refer to the Cellular RN in [1], which presents STM32 FW size figures (Flash and RAM) for both IP modes.

Note: STM32 FW for STM32L496 devices (“L496”) can be used on the 32L496GDISCOVERY Discovery board (with screen) as well as host board of the P-L496G-CELL01 and P-L496G-CELL02 Discovery packs (screenless).

When HW and PC are connected by means of the USB cable, the related drive is available on the PC. Drag and drop the chosen FW into that drive. Wait a few seconds that the FW file disappears from the file manager: this indicates that FW is programmed into the STM32 MCU.

Note: The X-CUBE-CELLULAR Expansion Package provides all the source files needed to build FW for the various supported IDEs.

3.4 Modem firmware version

The modem factory FW version in the user's HW may not be compliant any longer with the latest X-CUBE-CELLULAR version.

The *Cellular RN* indicates which modem FW version must be used (refer to [1]). The modem FW version must be checked in the serial terminal trace and updated if needed. Three methods are proposed, depending on the three different modem providers:

- For Quectel UG96 and BG96(1), the material needed is included in the X-CUBE-CELLULAR Expansion Package under the `\Utilities\Modem_FW\` directory. Open the `zip` file to retrieve all the requested information: documentation, tool, and firmware.
- For Sequans®, information is available from www.sequans.com/gm01q-stmod

1. *For the BG96 from a brand new kit, FW upgrade is mandatory.*

4 Run X-CUBE-CELLULAR firmware

4.1 Functional content of the X-CUBE-CELLULAR Expansion Package

X-CUBE-CELLULAR provides six applications included in the sample folder (`Middlewares\ST\STM32_Cellular\Samples`):

- *Echo Client* sends TCP / UDP data to a remote server; the expected result is to receive the same data back from the server
- *PING Client* allows the user to send a `PING` command and see the result in the terminal on the connected PC
- *HTTP Client* sends data to the cloud (GroveStreams) in order to update a dashboard; it can also receive data from the cloud
- *MQTT Client* sends and receives data over the MQTT protocol. There is a Node-RED® dashboard associated with the MQTT broker
- *COM Client* provides examples of interaction with the Com library for other services than socket (such as ICC interaction)
- *Custom Client*, an empty usable application, where specific code can be included and run

Note: Node-RED is a registered trademark of the OpenJS Foundation in the United States and/or other countries.

4.2 Set the serial terminal configuration for X-CUBE-CELLULAR firmware

Start Tera Term, select the proper connection (featuring the *STMicroelectronics* name), and set the parameters (the baud rate is different from the one indicated in Section 3.2 Activate the eSIM (optional)):

- 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

4.3 Start X-CUBE-CELLULAR firmware

Restart the board by pressing the black reset button.

Traces are displayed on the serial terminal, starting with a menu, which offers several options to the user:

- Wait for the timer to trigger FW
- Press any key (except [**1**], [**2**] and [**3**]) for immediate boot
- Press [**1**] to setup the FW configuration
- Press [**2**] to display the FAQ
- Press [**3**] to boot only the modem

Setting the APN is often needed prior to the boot because it depends on the SIM operator. In such case:

1. First press [**1**] before the end of the timer duration for FW configuration
2. Then press [**2**] for cellular services to set up the SIM parameters
3. Once the setup is done, exit from the menu, which boots the board

Once the board boots, the following is displayed in the Tera Term window:

1. Traces of network registration
2. Device IP address
3. Traces of the running *Echo Client* application that starts running and exchanges data with the remote server

If the process described in this section does not occur as expected, refer to Section 5 Troubleshooting.

Note: The "Echo Client" application is the only one activated by default. See the next sections for the activation of other applications.

4.4 *PING Client* demonstration

The *PING Client* pings any remote server and measures the round-trip delay. It is run by entering in the serial terminal:

- `ping` to ping the predefined remote server (default `8.8.8.8`)
- `ping xxx.xxx.xxx.xxx` to ping IPV4 address `xxx.xxx.xxx.xxx` of the remote server

The result of the *PING Client* demonstration is displayed on the serial terminal.

4.5 *HTTP Client* demonstration

The *HTTP Client* demonstration activates and operates GroveStreams cloud access.

User actions are requested prior to runing the *HTTP Client* demonstration:

1. Creation of a GroveStreams account at grovestreams.com
2. Configuration of STM32 FW accordingly(1)

1. *The detailed configuration information is provided in [3].*

Once GroveStreams parameters are set, start the *HTTP Client* demonstration by entering `httpclient on` in the serial terminal. Data are sent to the user's GroveStreams account where they are visible in the user's dashboard. The user can also interact with his HW through the GroveStreams dashboard, turning a LED button on and off.

Note: The Echo application keeps running unless `echo off` is entered in the terminal.

4.6 *MQTT Client* demonstration

The *MQTT Client* sends data to the MQTT broker (server) in the publisher role, and receive data from the MQTT broker in the subscriber role.

A Node-RED® application runs at the MQTT broker. The Node-RED® application is notified when data is sent by the device and can send data to the device. The user interface is the Node-RED® dashboard.

User actions are requested prior to runing the *MQTT Client* demonstration:

1. Setup a an Internet server with MQTT broker and Node-RED®
2. Configuration of STM32 FW accordingly(1)

1. *The detailed configuration information is provided in [3].*

Once these actions are performed, start the *MQTT Client* demonstration by entering `mqttclient on` in the serial terminal.

4.7 *COM Client* demonstration

The *COM Client* demonstration sends various commands to the Com library modules (except sockets commands that are already used by previous client demonstrations).

In the current version, the *COM Client* sends commands to ICC (using the CSIM protocol: APDU sends to the SIM through the modem by using the AT command `AT+CSIM`).

Start the *COM Client* demonstration by entering the following commands in the serial terminal:

- `comclt icc imsi`: requests and displays the IMSI
- `comclt icc iccid`: requests and displays the ICCID
- `comclt icc`: tests all predefined ICC commands

4.8 Run-time configuration

During FW execution, the command-line interface (CLI) is entered by pressing the [**return**] key. For example, the `help` command lists all available components.

Command examples:

- `cst info`: provides information about cellular network
- `trace off` : stops the trace
- `echo off`: stops the *Echo* application

The CLI and traces are displayed on the same terminal.

5 Troubleshooting

5.1 Excessive network attachment duration

Especially for BG96 modems that have all bands selected, it is interesting to configure the bands to scan, according to the device location and radio environment. It is not possible to configure the bands on UG96 modems. Band configuration is automatic on Sequans® modems.

When no M1 / NB1 network is available, the 2G fallback can last several minutes. It is then recommended to reduce the technology (only 2G or M1 and 2G), and also reduce the scanned bands.

To do this, boot FW, select choice [**2**] from the menu (refer to Section 4.3 Start X-CUBE-CELLULAR firmware), and then use AT commands to setup the modem.

As a result, observe the cellular technology (LTE Cat M, NB-IoT, GSM) and the bands used from the trace at boot time as illustrated by the example below:

```
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:>>>>> ............................... <<<<<
```

Regarding the rank numbers, the scan starts with M1, continues with GSM and finally ends with NB1.

AT commands `trace on` and `modem config get` provide the current activated bands.

As a matter of example, for configuring first with the B13 band in M1, then all bands in GSM, and finally the B4 band in NB1, type the [**return**] key to get the prompt and enter the following commands:

```
modem config iotopmode ALL
modem config nwscanmode AUTO
modem config gsmband any
modem config m1band B13
modem config nb1band B4
modem config scanseq M1_GSM_NB1
modem config send
```

Once this is done, reboot the STM32 board by pressing its black reset button.

Note:

1. *The `modem` command displays the possible commands for modem management, such as `modem help`*
2. *After the last command is sent (`modem config send`), the modem is programmed and saved. Performing the configuration at each boot is not needed*
3. *The new parameters are effective only after reboot*
4. *The user can restore the default parameters by using command `modem config send` alone*

6 Deep dive in X-CUBE-CELLULAR

Refer to [3] to know more about the possibilities of the X-CUBE-CELLULAR Expansion Package.

Revision history

Table 3. **Document revision history**

Date	Version	Changes
22-May-2019	1	Initial release.
22-Jul-2019	2	Introduced STM32CubeIDE support. Reorganized document structure and updated *Section 2 Overview of available documents*, *Section 3.2 Activate the eSIM (optional)*, *Section 3.3 Program firmware into the STM32microcontroller*, and *Section 3.4 Modem firmware version*.
9-Apr-2020	3	Added the *MQTT Client* and *COM Client* demonstrations: • Added Section 4.6 MQTT Client demonstration and Section 4.7 COM Client demonstration • Updated Section 4.1 Functional content of the X-CUBE-CELLULAR Expansion Package

Contents

List of tables

List of figures