LARA-L6 / LARA-R6 series

Application development guide

Application note

Abstract

This document provides detailed technology architecture and examples of how to use AT commands with u-blox LARA-L6 and LARA-R6 series modules.

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1 Getting Started

This document provides guidance for developing applications that interface with the u-blox LARA-R6 and LARA-L6 series module, including examples of AT command sequences for specific use cases.

Figure 1 shows the supporting documentation through the product design lifecycle. Table 1 provides summary of the key information contained in each of them.

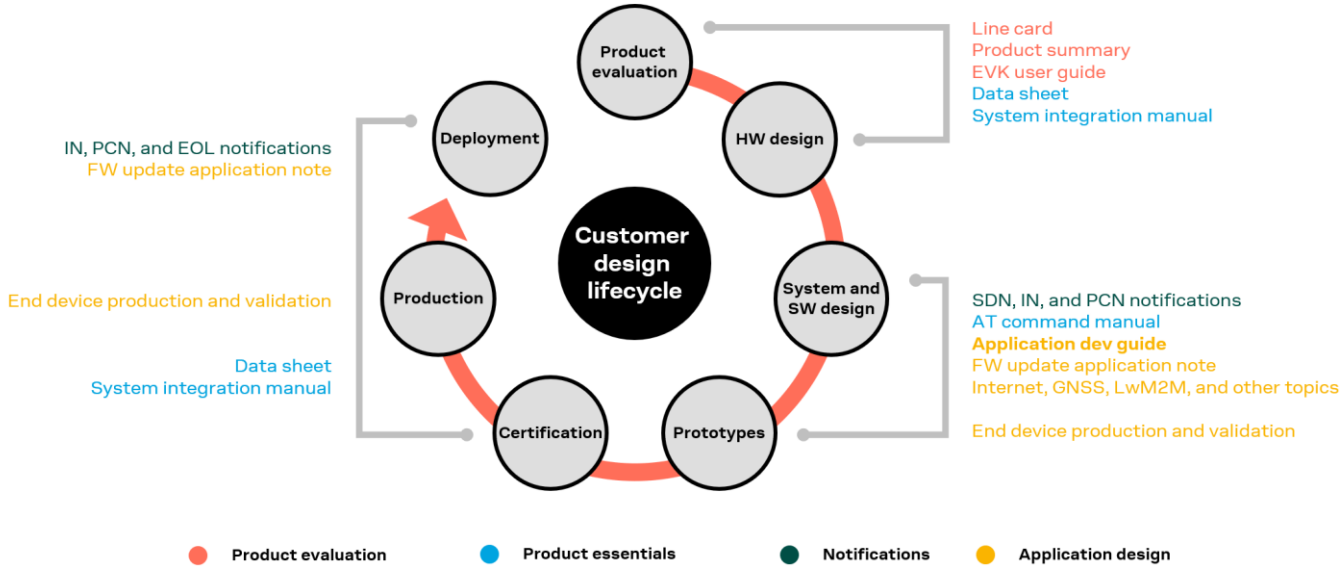

Figure 1: u-blox product documentation map

Document scope	Document name	Notes
Product evaluation	EVK-R6 user guide [12]	Starting guide for the LARA-R6 evaluation kit.
Product essentials	Data sheet [2][3]	Performance and characteristics of a product (family)
	System integration manual [4]	Describes how to design a product (family) into a customer application
	AT commands manual [1]	Reference guide for protocols, detailed AT command descriptions.
Notifications	Sample Delivery Note / Information Note / Product Change Note / End of Life	Notifications of SW / HW / Certification changes.
Application design	Application development guide	This document. **Start here!**
	FW update app note [6]	FW update procedures (uFOTA, FOAT, FOTA, +UFWINSTALL, EasyFlash).
	Production and validation test app note [13]	Guidelines of OEM production test and validation test. Contact tech support for this document.
	Positioning implementation app note [8]	GNSS interface and aiding clients. Techniques for hybrid positioning and timing indication.
	Linux integration app note [5]	Module integration on Linux OS platforms with RmNet and CDC-ECM technologies.
	Audio app note [11]	Audio functionality and tuning information.
	Mux implementation [9]	Use of multiplexer with cellular modules.
Tools	m-center AT scripts collection	https://github.com/u-blox/m-center

Table 1: LARA-R6 / LARA-L6 documentation overview

☞ An index finger points out key information pertaining to module integration and performance.

⚠ A warning symbol indicates actions that could negatively impact or damage the module.

2 Application design and development

When designing a host application interfacing with a u-blox cellular module, consider the points depicted in Figure 2:

- Choose the module's features that the application needs and the ones that can be disabled.
- Split the application workflow into stages.
- Design the application to work in several modes, reflecting the lifecycle steps of the product.

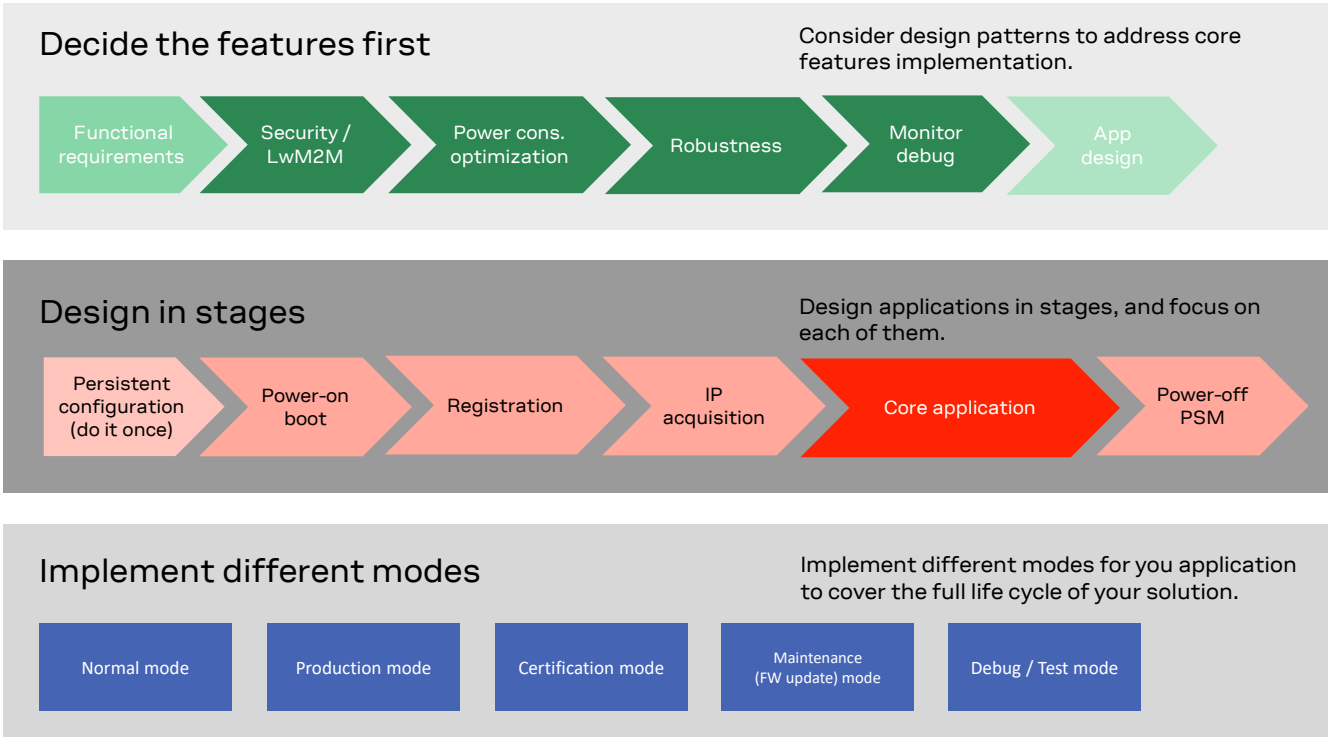

Figure 2: Application design guidelines

2.1 Initial design decisions and recommendations

If some features will never be used during the application lifetime, they should be disabled or properly configured to minimize their impact on the overall performance. These decisions should be carefully taken at design stage because any late change could cause much effort to adapt and validate the application.

These decisions concern:

- Usage of an LwM2M client
- Usage of security suite features
- Usage of power saving
- SIM card/MNO selection
- SW/HW monitor and debug solutions
- SW/HW recovery modes

An LwM2M client is necessary to allow MNOs to contact the device and retrieve diagnostic information; it enables also automatic periodic check of availability of FOTA updates, on both MNO and u-blox servers. Based on the target power consumption profile, the customer application can periodically enable the client in order to control features, such as the periodic LwM2M registrations with the server or can implement alternative or additional methods to implement FW updates when triggers by e.g., prolonged out of service conditions or by specific events.

Similar considerations hold for the security client.

Power saving features (+UPSV, eDRX) shall be configured based on the target power consumption profile.

The MNO profile (section 5) to be used depends on the type of application and SIM card (regional or global roaming). If the SIM card belongs to an MNO for which the module has gained the type approval, the MNO profile is available in the FW and shall be used.

Debug-ability can be provided via test endpoints, access to the USB interface, and in general a prolific application log containing all AT commands strings exchanged with the module and diagnostic information sent by the module with timing information. Monitoring the module status is a requirement to implement, via HW or SW, recovery procedures as described in section 8.

u-blox recommends properly designing and testing a module's firmware update mechanism that allows deployment of the latest cellular module FW in the field after the device production.

☞ The LWM2M client may be enabled or disabled by default depending on the MNO profile configuration and the product variant. To check default configuration, refer to Appendix C: Mobile Network Operator profiles of the AT commands manual [1]. In general, it is suggested to disable the LwM2M client, especially when the related features are not explicitly required by the MNO and not needed by the user.

2.2 Application stages

2.2.1 Persistent configurations

Some module settings are persistent, i.e., they are stored in the module non-volatile memory (NVM). Among these are the MNO profile (see section 6), APN for Internet connectivity, and active LTE bands.

The host application should implement a persistent configuration setting phase, performed once and then at an as-needed basis, where all AT commands related to the required settings are issued.

☞ See the LARA-R6 FW update application note [6] for persistence of settings after a FW update. If settings are not retained, they shall be reapplied.

2.2.2 Power on/boot

In general, at each boot the application should read configurations and make sure they are correct. If not, persistent configurations can be reapplied.

Not all the module configurations are persistent. Therefore, the application, after each module boot, should again set these volatile configurations (for example, AT+CMEE=2, URC enabling).

It is very important that the application has a robust mechanism to detect when the module is ready to communicate via AT commands at the power-on: a solution is to enable the greeting message (+CSGT AT command); alternatively, the host application can wait for a response to "AT" command.

The application should configure module time. Automatic update of local time with the network time information is the factory-programmed setting (+CTZU: 1), so after LTE attach, the time of the module is generally updated.

2.2.3 Network registration

For details about the network registration stage, see section 7.1.

2.2.4 IP acquisition

For some details and guidelines on this topic, see the LARA-R6 Internet applications development guide application note [7].

2.2.5 Core application

For some details and guidelines on this topic, see the LARA-R6 Internet applications development guide application note [7] and LARA-R6 series AT command manual [1]. The application shall handle AT commands, responses and unsolicited indications as suggested in section 3. For diagnostic purposes, the application should rely on status AT commands, see section 8.1. For robustness purposes, the application should implement embedded watchdog procedures, see section 8.2.

2.2.6 Power-off

The application might need to switch off the module; both normal and emergency shutdown are described in the LARA-R6 series system integration manual [4].

2.3 Application modes

An application is usually designed based on the main use cases in actual scenarios. This way of operation is what we call “normal mode”. In addition, the designer should provide a way to configure the application for more specific contexts, which can have different requirements with respect to normal mode and can help to perform other important steps in the product lifecycle.

2.3.1 Debug / test mode

In general, an application should always output a significant log, including the AT commands it issues and their responses, and implement monitoring strategies as described in section 8.

If a problem occurs related to the cellular module and more information is needed, it may be necessary to configure different verbosity levels for the host application and modules log. In extreme cases, it may be necessary to provide an AT interface passthrough to allow access to diagnostic AT commands.

If the cellular communication is tested against a network simulator, use a suitable test SIM card (usually provided by the network simulator manufacturer). If a test SIM card is not available, make sure to disable authentication and integrity checks on the tester side (by proper setting) and on the module (by using the AT+UDCONF=81,0 command, see LARA-R6 series AT commands manual [1]).

2.3.2 Production testing

This mode is to be used during the production tests of the end device. In this scenario the main application is usually inactive, and AT commands can be used to properly configure the module and use its end user testing features. For more details, contact technical support production and prototype validation guidelines application note.

2.3.3 Certification mode

Depending on the kind of certification, such as regulatory, conformance or for MNO type approval, the application might be disabled, and the module externally controlled (for example, for throughput testing). Specific MNO tests might require the application to be running in normal mode (for example, remote SIM provisioning, FOTA).

2.3.4 Firmware update mode

A module’s firmware update procedure should be implemented when necessary, either over the air or tethered. Each update strategy has its requirements and correct implementation, which should be

followed to guarantee the success of the operation. For more details, see the LARA-R6 FW update application note [6].

3 AT commands response parser

It is important that the user implements a dedicated AT parser component in the host application.

Basic guidelines:

- When entering AT commands, spaces are ignored.
- The DTE shall handle the case of unexpected spaces or line endings, i.e., the <CR><LF> characters.
- As suggested in the LARA-R6 series AT commands manual [1], always wait for at least 20 ms following a final result code or a URC reception before issuing a new AT command.
- When the module has finished processing an AT command, it will output a final result code (either OK or ERROR) indicating that it is ready to accept a new AT command. The information text responses are issued before the final result code. Change the +CMEE AT command setting to numeric or verbose value (for example, AT+CMEE=1 or AT+CMEE=2).
- Asynchronous commands (for example, +UMQTTC) return an immediate final result code and final result via URC.
- Some AT commands return an intermediate result code (IRC) during command execution.

AT commands executed on different AT capable interfaces, are serialized and then executed by the internal AT parser in the arrival order; parallel AT commands execution is not possible.

This behavior can be detected in the following configurations:

- AT commands executed in main and auxiliary UART interface
- AT commands executed on one serial-over-USB interface and one UART interface
- AT commands executed on two different serial-over-USB interfaces
- AT commands executed on two different MUX virtual channels over UART interface

The only exception to previous rule is when it is defined a system architecture with a PPP dial-up on one port and AT commands on the other one.

3.1 Operational modes of the AT interface

When implementing the AT parser, it is important to consider that the communication port, whether a virtual serial ports over USB interface, the main and auxiliary UART or a MUX virtual channels, enters different operational modes while processing AT commands.

In command mode, the module (called DCE – data communication equipment) can receive AT commands. Once an AT command is detected on the AT interface, the DCE processes it and may return to command mode by issuing a success or error response. Special AT commands lead the AT interface into intermediate states where, for example, an SMS payload is expected, or raw/binary data is exchanged (for example, during file transfer), or PPP packets are exchanged. In the latter case, the PPP data mode can be temporarily exited by a special +++ packet or DTR line ON-to-OFF transition and the online command mode (OLCM) state is entered: from this state, which is similar to the command mode, the DCE can be moved back to PPP data mode via ATO command or can disconnect PPP via ATH command (having previously applied AT+CVHU=0).

Figure 3 depicts the various modes in which the module can operate and shows the actions that cause transitions between the different modes. The transitions triggered by DTR line changes are configurable with the AT&D command, see the AT commands manual [1].

For more details about the AT command interface settings, see the AT command settings section in the AT commands manual [1].

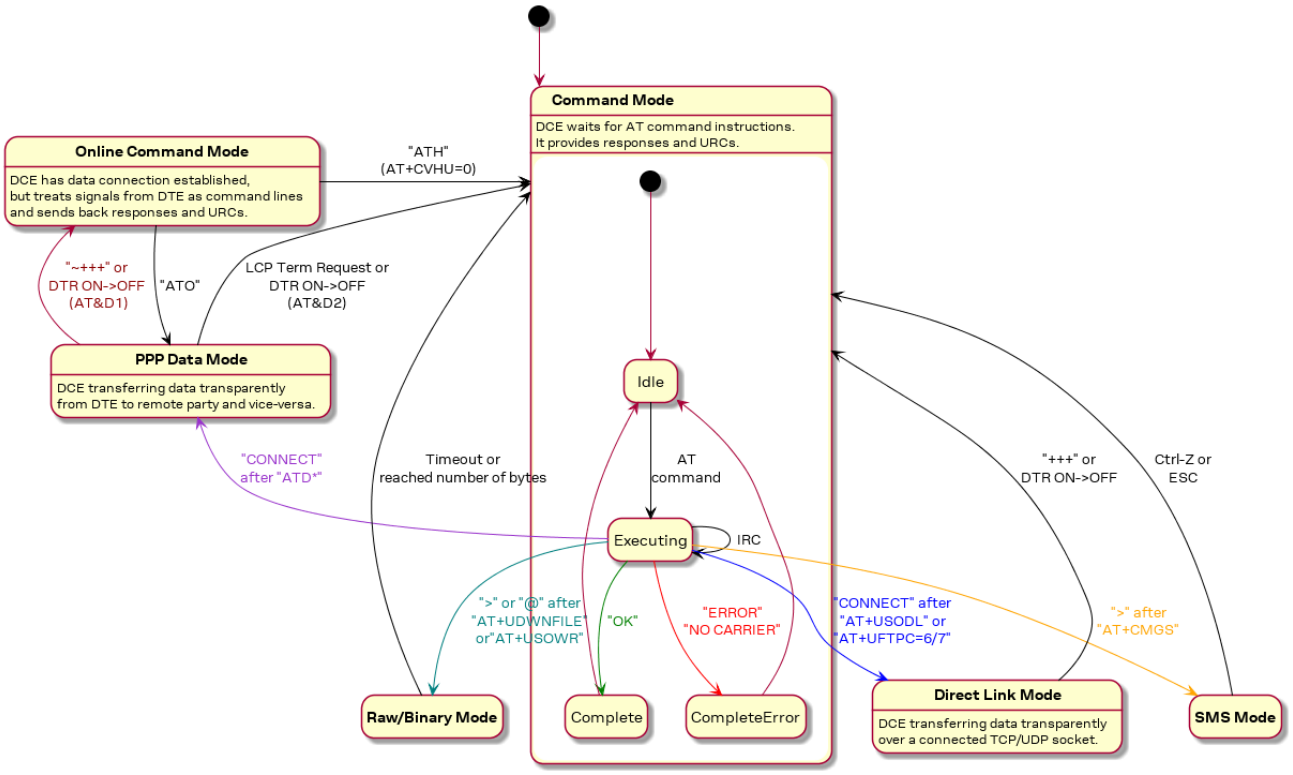

Figure 3: Module operating modes and actions causing mode transitions

3.2 Unsolicited result code

An unsolicited result code (URC) is a string message (provided by the DCE) that asynchronously indicates the occurrence of an event that might be related to a previous AT command or to the feature the user is currently using, or to the module's autonomous activity (for example, due to mobility).

When a specific URC has been enabled, it can be output at any time to report a relevant event or status change on all AT ports. If an AT port is busy, the application can decide to discard +CIND, +CGEV and SMS related URC by properly configuring the related AT commands; all other URCs will be deferred and printed when the AT port returns into command mode.

By default, all AT ports are enabled for the reception of URCs, anyway it is possible to exclude some of them, by means of the +UURCCONF AT command.

☞ The +UURCCONF is volatile and is reset to its factory-programmed setting at each reboot.

Command	Response	Description
Enabling the feature at each module reboot		
AT+UURCCONF=2	OK	The feature is active, and URCs are disabled on all terminals.
AT+UURCCONF?	+UURCCONF: 2,0,0 OK	The read command confirms that the feature is active, and no AT terminal is enabled for URC display.
AT+UURCCONF=1	OK	The AT terminal on which the AT command has been give is now enabled for URC display.
Read example		
AT+UURCCONF?	+UURCCONF: 1,1,1 OK	The read command given on an URC enabled AT terminal confirms that the latter is in the list.
AT+UURCCONF?	+UURCCONF: 1,0,1 OK	The read command given on a different AT terminal confirms that the latter is not in the list and hence it is not enabled for URC reception.
Disabling the feature		
AT+UURCCONF=0	OK	The feature is disabled, URCs will be displayed on all active AT terminals.

Command	Response	Description
AT+UURCCONF?	+UURCCONF: 0,0,0	The read command confirms that the feature is disabled.

Table 2: +UURCONF examples

Due to race conditions in mode transitions, URCs can be received after an AT command has been transmitted by the host application.

URCs are sent to all available AT interfaces when the MUX is used.

Examples of some URCs are shown in Table 3.

URC	Description
+CEREG: <stat>[,<tac>,<ci>,<AcT>]	Network registration status or location has been updated
+CGEV: ME PDN ACT <cid>[,<reason>[,<cid_other>]]	The MT has activated a primary PDP context
+ULWM2MSTAT: <event>,<param1>[,<param2>]	LwM2M URCs generic syntax
+UUSOCL: <socket>	Socket has been closed

Table 3: URCs examples

4 Local connectivity

4.1 Serial interface configuration

By default, USB and UART interfaces are available simultaneously. It is possible to switch between 5 serial interface configuration variants, using the command +USIO AT command, as shown in Table 4.

Command	Response	Description
AT+USIO=0	OK	(Default configuration) AT on MAIN UART (9-wire: RXD, TXD, CTS, RTS, DTR, DSR, DCD, RI, GND) AT on USB (x2) Diagnostic on USB
AT+USIO=1	OK	AT on MAIN UART (5-wire: RX/TX, CTS, RTS, GND) AT on AUX UART (5-wire: RX/TX, CTS, RTS, GND) AT on USB (x1) Diagnostic on USB
AT+USIO=2	OK	AT on MAIN UART (9-wire: RXD, TXD, CTS, RTS, DTR, DSR, DCD, RI, GND) AT on USB (x1) GNSS tunneling on USB (x1) Diagnostic on USB
AT+USIO=3	OK	AT on USB (x2) GNSS tunneling on USB (x1) Diagnostic on USB
AT+USIO=4	OK	AT on USB (x3) Diagnostic on USB
AT+USIO=5	OK	AT on MAIN UART (5-wire: RX/TX, CTS, RTS, GND) AT on USB (x1) Diagnostic on AUX UART (5-wire: RX/TX, CTS, RTS, GND) ☞ Configuration not supported by LARA-R6 series module.

Table 4: +USIO configuration variants

☞ Reboot the module to apply the new +USIO configuration.

4.2 AT interface on UART

AT commands can be issued to the module via UART interfaces, with default data rate set to 115.2 kbit/s (230.4 kbit/s, 460.8 kbit/s, 921.6 kbit/s and 3 Mbit/s are supported too). “Auto-bauding” is not supported by LARA-R6 series modules.

4.2.1 Set a fixed baud rate

Use the +IPR AT command to set a different baud rate for the UART interface in which the command is sent, as shown in Table 5.

Command	Response	Description
AT+IPR=460800	OK	Set UART speed to fixed value 460800 bit/s. Cellular module response is sent at 115200 bit/s, i.e., at the original baud rate value.
After the “OK” final result code, wait for at least 200 ms before issuing a new AT command, to guarantee proper baud rate reconfiguration. Then send commands at the speed just set (460800 bit/s in the example).		
The new selected baud rate is immediately applied, a device reboot is not needed.		
AT+IPR?	+IPR: 460800 OK	Check the current baud rate

Table 5: Setting a fixed baud rate example

☞ The baud rate configured for main UART is persistent across power cycles, while that for auxiliary UART is volatile.

☞ The UART speed takes around 200 ms to reconfigure itself after a baud rate change through the +IPR AT command.

☞ To show a greeting text at module boot (+CSGT AT command), set the desired fixed baud rate beforehand by using the +IPR AT command. If active, the greeting text is shown at boot once, on any AT interface, the first time the TE sets the DTR line to ON state.

4.2.2 Auxiliary (AUX) serial interface configuration

If the auxiliary UART interface is enabled via the +USIO AT command, then it may be necessary to configure this serial interface from the main UART interface, especially for the first use and when the factory-programmed configuration does not match the desired settings.

Table 6 shows how the +UUARTCONF AT command applies the desired settings. For additional details, see the LARA-R6 / LARA-L6 series AT commands manual [1].

Command	Response	Description
`AT+UUARTCONF=1,115200,3`	`OK`	Set the desired baud rate and flow control mode for the auxiliary UART interface.

`AT+UUARTCONF?`	`+UUARTCONF: 0,115200,3`
	`+UUARTCONF: 1,115200,3`
	`OK`
		Check the current settings for both the main UART and the auxiliary UART interfaces.

`AT+UUARTCONF=?`	`+UUARTCONF: 1,(115200,230400,460800,921600,3000000),(0-3)` `OK`	Visualize the possible settings to be applied in the auxiliary UART handling.

Table 6: +UUARTCONF variants description

☞ Configuration changes performed by the +UUARTCONF AT command are stored in the NVM and applied to the auxiliary UART interface at the next module boot.

☞ The **Set** command is available only for the auxiliary UART interface. The **Read** command is available for both the main UART and the auxiliary UART interfaces.

4.2.3 Configure flow control

The flow control can be configured by of the &K AT command for the main UART or by the +UUARTCONF for the auxiliary UART.

☞ The &K setting for auxiliary UART is volatile.

☞ The +UUARTCONF setting for auxiliary UART is saved in NVM but it requires a reboot to become effective.

☞ The &K setting takes around two characters transmission time (with respect to the current baud rate) to reconfigure after the command has been issued.

☞ The hardware flow control cannot be changed when +USIO: 1 and +UPSV: 1.

4.2.4 Notification and URCs

The Ring Indicator line behavior can be customized by the +URING AT command. By default (+URING: 0), the line is asserted only on incoming call and incoming SMS but can be asserted also for all URCs (+URING: 1), for all incoming data (+URING: 2) and for all URCs and all incoming data (+URING: 3).

☞ The Ring Indicator line is not supported when main and auxiliary UARTs are both enabled in 5-wires mode (+USIO: 1) and when main UART interface is disabled (+USIO: 3 and +USIO: 4). In these cases, it's necessary to configure one of the GPIO pins as a Ring Indicator line (<gpio_mode> = 18) by means of the +UGPIOC AT commands.

Further information on the URCs reception can be found in section 3.2.

4.3 AT interface on USB

AT commands can be issued to the module via the AT enabled ports on the USB interface. The functionality of the four ports available over the USB interface can be modified by the +USIO AT command.

☞ The USB interface is enabled only if an external voltage detectable as high logic level is applied at the **VUSB_DET** input pin during the switch-on boot sequence of the module.

4.4 USB network modes

☞ LARA-R6 "00B" product version does not support network connectivity modes over USB.

Regardless of the selected RAT, packet switched connectivity over USB interface can be established in two different modes:

- **RmNet** mode: Qualcomm mobile station modem (MSM) Interface (QMI) defines the DCE-DTE interface, which exposes various functionalities of MSM, including tethered networking. On the host side system, the RmNet device (LARA-L6) appears as an ethernet adapter without ethernet framing/MAC support.
- **ECM** mode: ECM is a protocol used to send and receive Ethernet frames over a USB. It can be used in conjunction with AT command ports. The module used through ECM supports both bridge and router mode.

To correctly detect all the USB components, dedicated USB drivers must be used. For Linux subsystems, refer to LARA-L6 series Linux integration application note [5]. For Windows system, download the LARA-L6 driver [20].

A module can be switched to RmNet or ECM mode issuing the following AT commands:

Command	Response	Description
AT+UUSBCONF=4,<network>	OK	Switch the module to USB net mode<network>: • "RMNET" • "ECM"
AT+CFUN=16	OK	Reboot the module. At next reboot, the restore action previously set is applied.

Table 7: USB net mode set AT command usage example

In RmNet and ECM mode the module exposes the following enumerated USB interfaces:

USB device order	Description
0	Diagnostic log port
1	AT commands and data
2	AT commands and data
3	GNSS tunnelling/AT commands and data (see 4.1 for the USB configuration)
4	RmNet/ECM interface

For more information on CDC-ECM and RmNet packet switched USB modes, see LARA-R6 / LARA-L6 series Linux integration Application note [5].

4.5 Power saving

The power saving configuration is disabled by default, but it can be enabled and configured using the +UPSV AT command. When the power saving is enabled, the module automatically enters the low power idle mode whenever possible, reducing current consumption. If the module is registered or attached to a network, the power saving periods are interleaved by wake-up phases in which the module monitors the paging channels, according to 2G/3G/LTE system requirements.

☞ Check LARA-R6 series AT commands manual [1] for details of +UPSV AT command functionality.

4.5.1 USB interface

The suspend / resume and remote wake up functionalities are supported by USB interface despite the +UPSV value configured.

4.5.2 UART interface

The +UPSV AT command can be configured in the modes below:

- **Power saving is disabled** (+UPSV: 0)
  The UART interfaces are always enabled, and the module does not enter in power save mode.
- **Power saving is enabled** (+UPSV: 1)
  The UART is re-enabled from time to time to allow the DTE to transmit, and the module switches from idle to active mode in a cyclic way. If during the active mode any data is received, the module remains active for the specified timeout.
  In this mode, if both main and auxiliary UART interfaces are active, the flow control shall be configured the same on both ports.
- **Power saving is controlled by DTR line** (+UPSV: 3)
  If DTR line is set to OFF the power saving is allowed, while if it is set to ON, the module exits from power saving.
  This mode is not supported when both main and auxiliary UART interfaces are active, unless a GPIO pin is configured as DTR line.

In case both UART interfaces are active (+USIO=1) and it is necessary to control the power saving feature by means of the DTR line (+UPSV=3), it's possible to configure the GPIO3 (pin 24) or GPIO4 (pin 25) as a DTR line (<gpio_mode> = 15) by means of +UGPIOC AT command.

If the power saving feature is active (+UPSV: 1 or +UPSV: 3), and the hardware flow control is enabled on the UART interface, and the RTS line is de-asserted by the DTE, then the URCs generated are buffered by the DCE, and the DCE power saving mode is inhibited until the DTE asserts the RTS line and receives the buffered URCs.

☞ The scenario above is also valid when the DCE is in mux mode, where physical RTS line must be handled for receiving buffered URCs.

4.6 Multiplexer (MUX)

LARA-R6 series modules support the multiplexer functionality on the UART physical link as defined in the 3GPP TS 27.010 [15]. This makes it possible to have multiple simultaneous sessions (virtual channels) over the single UART interface.

The following virtual channels are defined:

- Channel 0: multiplexer control.
- Channels 1 to 2: AT commands / data connection.
- Channel 3: GNSS data tunneling (NMEA).

For further details about the usage of multiplexer with LARA-R6 series modules, see the Mux implementation in cellular modules application note [9].

☞ The UART interface takes around 200 ms to reconfigure itself after the multiplexer configuration through the +CMUX AT command.

☞ Parallel AT commands execution is not possible on different MUX channels; further details in section 3.

☞ URCs are sent to all available AT interfaces when the multiplexer functionality is applied. To configure URC behavior, see section 3.2.

4.7 Point-to-point protocol (PPP)

Data (PSD) calls are possible over all interfaces.

☞ If the double UART configuration is used, the full V24 modem lines are not supported. In this configuration, entering in OLCM or disconnecting the PPP connection via DTR line de-assertion is not possible.

☞ Issue the AT+CVHU=0 command to make ATH over Online Command Mode (OLCM) work, according to 3GPP requirements. If the module has a DUN/PPP activated and is in OLCM, the command deactivates the PPP and the associated PDP context (if possible).

☞ When UART interface is used in a configuration where physical DTR line is present, to start a PPP connection, the DTR line must be asserted.

☞ When USB interface is used to start a PPP connection, the virtual DTR line must be asserted.

Further information about PPP dial-up establishment can be found in the LARA-R6 Internet applications development guide application note [7] and in the EVK-R6 user guide [12].

5 User settings persistence

5.1 Save user settings

When an AT command is executed in set mode, if the user setting should be persistent between power cycles, the value is automatically stored in NVM. No other action is required to the user.

Check LARA-R6 / LARA-L6 series AT commands manual [1] appendix to identify the AT commands with settings persistent in NVM and their factory programmed value.

☞ To avoid flash memory wearing, it is strongly recommended to read the required user setting value and then, if necessary, to save the new user setting, instead of setting the new value directly.

5.2 Restore factory configuration

During operation with the module, different files may be stored in the module's file system. Similarly, the NVM is populated with user configuration and auxiliary information stored by the module to optimize its operations (e.g., information on the cellular environment).

The host application can restore the module factory configuration via the +UFACTORY AT command. This can be required to recover from an unexpected behavior and restart the module in a controlled configuration, or during the MNO certifications, where the device is tested in various simulated scenarios and the auxiliary information or previous user settings can affect the tests outcome.

Restoring the factory configuration of the module takes two steps:

1. Set the type of restore to perform, using the +UFACTORY AT command. FS and/or NVM can be restored.
2. Reboot the module.

The +UFACTORY AT command writes a flag in NVM and does not perform any restoring action. This flag is then read **at the next reboot,** when the +UFACTORY corresponding action is executed. Therefore, it is possible to cancel the +UFACTORY action by issuing the AT+UFACTORY=0,0 command **before the reboot**.

Table 8 shows some examples.

Command	Response	Description
Delete all user files previously saved with USER flag in the file system		
`AT+UFACTORY=1,0`	`OK`	Set +UFACTORY to delete all user files previously stored with USER flag in the file system. No restore is performed so far.
`AT+UFACTORY?`	`+UFACTORY: 1,0` `OK`	Check the restore action currently set.
`AT+CFUN=16`	`OK`	Reboot the module. At next reboot, the restore action previously set is applied.
Delete MNO profiles in NVM		
`AT+UFACTORY=0,1`	`OK`	Set +UFACTORY to delete all MNO profiles, except native MNO profiles are to be reset. No restore is performed so far.
`AT+UFACTORY?`	`+UFACTORY: 0,1` `OK`	Check the restore action currently set.
`AT+CFUN=16`	`OK`	Reboot the module. At next reboot, MNO profiles are reverted to the factory programmed values.
Restore UART and +UPSV settings to default in NVM		

Command	Response	Description
AT+UFACTORY=0,2	OK	Set +UFACTORY to restore UART and +UPSV settings to default in NVM. No restore is performed so far.
AT+UFACTORY?	+UFACTORY: 0,2 OK	Check the restore action currently set.
AT+CFUN=16	OK	Reboot the module. At the next reboot, UART and +UPSV settings are reverted to the factory programmed values.
Cancel a delete operation (before reboot)		
AT+UFACTORY=1,0	OK	Set a +UFACTORY action.
AT+UFACTORY?	+UFACTORY: 1,0 OK	Check the action currently set. In this example, a delete user files procedure is requested and will be applied at the next reboot.
AT+UFACTORY=0,0	OK	Cancel any delete action.
AT+UFACTORY?	+UFACTORY: 0,0 OK	No delete action will be applied at next reboot.

Table 8: +UFACTORY AT command usage examples

☞ After having issued a +UFACTORY AT command with <nvm_op>=1, a second reboot is required to make the module again ready to properly accept and store new settings to NVM.

☞ Restoring UART and the +UPSV setting to the default using +UFACTORY=0,2 also means that the +USIO mode will be restored to the factory-programmed setting.

6 MNO profiles

MNO profiles provide a powerful and flexible method to configure the LARA-R6 series module to seamlessly work with the SIM of the selected network operator.

Using the MNO profiles the module is dynamically configured to use the proper bands, RATs, and the operator-dependent protocol stack settings needed to operate on the home network in full compliance with the mobile operator requirements.

With the MNO profiles, a customer application is not required to configure the module using complex and/or network-dependent parameters but benefits from a “out of the box” solution that provides seamless connectivity while abstracting the complexity of managing individual network configurations.

Use the +UMNOPROF AT command to select a profile for the network operator. For more details on the +UMNOPROF AT command and the MNO profile settings, see the LARA-R6 series AT commands manual [1].

☞ On LARA-L6 series modules only the MNO profiles: 1, 90 and 201 are supported.

6.1 Using MNO profiles

To configure the module to use an MNO profile, first make sure the module is de-registered from the network, then select the profile using the ID number and finally software-reset the module. When the module reboots, it will configure itself to use the parameters specified by the MNO.

☞ The host application should specify an MNO profile. The default and factory-programmed MNO profile is 90 (global profile).

☞ Reboot the module by means of AT+CFUN=15 command (or the equivalent AT+CFUN=16) to make the MNO profile active.

6.2 Modifiable parameters

MNO profiles configure the module with a set of parameters. Some of these parameters can be overridden by using AT commands:

- +UBANDMASK allows to enable/disable the cellular bands;
- +CGDCONT allows to configure APN and PDP type.

If the host changes any of these parameters, they will be retained after a module reset; if the MNO profile is re-applied, after reboot the MNO profile specific settings will be restored to the factory-programmed setting.

After setting the MNO profile the application may want also to modify the Radio Access Technology list and the bands to be enabled or disabled.

Possible reason for setting +URAT may include application workaround for specific interoperability issues, e.g., due to 3G sunset (see section 7.3.1.2), and temporary setting for test purposes, e.g., to verify the device behavior in all visible RATs.

Possible reason for setting +UBANDMASK may include:

- Usually, the APN will be accepted also when in roaming, but bands might need to be enabled to search for alternative PLMNs;
- The device is an area where it is interested in running on specific bands only;
- Band is not fully deployed by carrier in the area the device is intended to run.

6.3 MNO profile setting examples

De-register the module before setting MNO profile, then reboot it to apply the setting (Table 9)

Command	Response	Description
AT+CFUN=0	OK	Turn-off radio functionality, the module will de-register
AT+UMNOPROF=2	OK	Set MNO profile for AT&T.
AT+CFUN=15	OK	Perform a module reset. After reboot, the MNO profile 2 settings are applied.

Table 9: Correct way of setting the MNO profile

6.4 T-Mobile US profile (+UMNOPROF: 5)

☞ On LARA-R6 and LARA-L6 modules series the IPv4 address translation functionality for IPv4 traffic enabling over IPv6-only networks (464XLAT) is disabled by default. For further details see the T-Mobile US data connection section in the Internet application development guide [7].

6.5 Global profile (+UMNOPROF: 90)

This is the default profile for the LARA-R6 & LARA-L6 modules, with all supported bands set as enabled on all available RATs. No factory-programmed <APN> is available for the initial default EPS bearer mapped to <cid>=1, so the user shall configure it (+CGDCONT) based on the inserted SIM before usage.

The <cid>=11 is configured with the APN 'ims' and it is used by IMS client. When in global profile (+UMNOPROF: 90) the IMS client runs with generic configuration, but this may not fit MNO requirements for IMS registration and VoLTE call functionality. See below table for known limitations and actions required.

MNO	Requirement	AT command	Persistent
Telstra (AUS)	SIP user agent must be configured to register to IMS	AT+UIMSCFG=0,1,31,"Telstra u-blox LARA-R6 X xx.xx"	Yes

6.6 AT&T profile (+UMNOPROF: 2)

LARA-R6 in AT&T configuration (+UMNOPROF: 2) is factory-programmed with a predefined string for the <APN> of the initial default bearer on <cid>=1 per AT&T requirement: a different APN is configured for data-only and VoLTE capable product variant. For more details, see the appendix related to MNO Profile in LARA-R6 / LARA-L6 series AT command manual [1]. The user can set a custom APN, which might be different from M2M and consumer SIM cards, used for live AT&T network attach via the +CGDCONT set. This setting is persistent.

Data-only devices are configured as data-centric and have the following APN configuration:

- <cid>=1: PDP type is Ipv4v6, APN is "broadband";
- <cid>=2: PDP type is Ipv4v6, APN is "attm2mglobal";
- <cid>=11: PDP type is Ipv4v6, APN is "ims";

Even if the APN is pre-defined, IMS client is disabled for VoLTE and SMS over IMS.

VoLTE capable devices are configured as data-centric and have the following APN configuration:

- <cid>=1: PDP type is Ipv4v6, APN is "nxtgenphone";
- <cid>=2: PDP type is Ipv4v6, APN is "attm2mglobal";
- <cid>=11: PDP type is Ipv4v6, APN is "ims";

IMS client is enabled for VoLTE and SMS over IMS.

☞ The <cid>=2 is used for LwM2M data connection to the AT&T server for device management purposes. This APN entry shall not be deleted/changed by the user.

6.7 FirstNet profile (+UMNOPROF: 206)

FirstNet is the AT&T nationwide high-speed wireless broadband network dedicated to public safety community. By setting the FirstNet profile (+UMNOPROF: 206) the interoperability with this network is optimized.

Data-only devices are configured as data-centric and have the following APN configuration:

- <cid>=1: PDP type is Ipv4v6, APN is “firstnet-broadband”;
- <cid>=2: PDP type is Ipv4v6, APN is “attiotfirstnet.fn”;
- <cid>=11: PDP type is Ipv4v6, APN is “ims”;

IMS client is disabled for VoLTE and SMS over IMS.

VoLTE capable devices are configured as data-centric and have the following APN configuration:

- <cid>=1: PDP type is Ipv4v6, APN is “firstnet-phone”;
- <cid>=2: PDP type is Ipv4v6, APN is “attiotfirstnet.fn”;
- <cid>=11: PDP type is Ipv4v6, APN is “ims”;

IMS client is enabled for VoLTE and SMS over IMS.

☞ The <cid>=2 is used for LwM2M data connection to the AT&T server for device management purposes. This APN entry shall not be deleted/changed by user.

6.8 Verizon profile (+UMNOPROF: 3)

Per Verizon requirement, the initial default EPS bearer (used by IMS), the administrative EPS bearers (used by BIP and LWM2M) and the EPS bearers used for data connectivity are pre-defined by default and are aligned to the entries of the Verizon APN table (see +VZWAPNE AT command description in LARA-R6 series AT commands manual [1]) and can be updated by Verizon via LwM2M provisioning.

Data-only products supporting Verizon profile are configured as data-centric and IMS client supports only SMS over IMS.

A brief description of the <cid>s in Verizon configuration is shown in the here below Table 10.

<cid> (context id)	APN	Description
1	ims	Initial EPS bearer, it corresponds to the first record of VZWAPNE.
2	VZWADMIN	Corresponds to the Class 2 record of the VZWAPNE and it is used by BIP.
3	VZWINTERNET	Corresponds to the Class 3 record of the VZWAPNE.
4	VZWAPP	Corresponds to the Class 4 record of the VZWAPNE and it is used for the VZW Application PDN.
6	VZWCLASS6	Correspond to the Class 6 records of the VZWAPNE.
7	VZWCLASS7	Correspond to the Class 7 records of the VZWAPNE.
8	VZWEMERGENCY	Correspond to the Class 0 records of the VZWAPNE.

Table 10: <cid>s description in Verizon MNO profile

☞ The only APN value which can be changed by user/application (with +CGDCONT) is the Class3, all other APN Classes must not be changed by user/application.

☞ When using the Verizon profile (+UMNOPROF: 3) in VZW HPLMN, the <cid>=1 is reserved for IMS (APN class 1) while the PDN connection shall be mapped to the <cid>=3 (APN class 3). If the Verizon profile is set, the preferred PDP default context is automatically configured to <cid>=3.

☞ For LARA-R6401D modules, in roaming condition, the PDN connection is maintained on <cid>=3 (APN class 3) with Ipv4-only type. While the <cid>=1 usually used for IMS (APN class 1) is not activated.

☞ The LwM2M client is enabled by default in the Verizon profile of all the LARA-R6 and LARA-L6 product versions.

6.9 GCF-PTCRB profile (+UMNOPROF: 201)

It is recommended to use this MNO profile during production or lab tests. With this profile, LwM2M is disabled.

From a regulatory perspective, MNO profiles do not affect the low-level RF performance of the module, which are the same regardless of the selected profile. Anyway, some profiles may enable features not available on a simulated network which are known to interfere with laboratory measurements. By setting the GCF-PTCRB profile (+UMNOPROF: 201) unexpected behavior during testing is reduced.

7 Cellular modem services

7.1 Network registration

At power-on the module reads the information in the currently selected MNO profile. It will use this information to configure which bands to scan, the radio access technology to use if more than one is supported, and other attach parameters like APN. Once the module has found a suitable cell it can camp on, it will start the registration process.

A new SIM can be activated after its first registration on a real network: its “profile” (e.g., contents of the SIM files) can be remotely provisioned over the air and a registration cycle is triggered at the end of the SIM OTA procedure via BIP.

It is important to set the operator profile first because this operation will configure the default RAT and band mask for that corresponding profile. If the +UMNOPROF set command is issued after the +URAT or +UBANDMASK AT commands, then it will override any past configuration the host application has made. The module is programmed with auto-cops, so no AT command is required to trigger the network registration.

The MNO profile to be selected shall match the SIM card provider and not the MNO on which the module is going to register, that is, with an AT&T SIM card the AT&T MNO profile shall be selected, with a Vodafone SIM card the Vodafone MNO profile shall be selected and so on. If there is no MNO profile matching the SIM card provider, then it is recommended to select a generic MNO profile (e.g., global profile, standard Europe, etc.).

Be aware that the settings of each MNO profile are aligned to the requirements of that MNO, so if the module will move to roaming MNOs, it might happen that some bands are disabled and need to be enabled. E.g., the AT&T MNO profile has the European (EU) bands disabled and if the device will roam in Europe, then the related EU bands shall be enabled manually.

7.1.1 RAT and Band configuration

For multi-RAT modules, user preferred RATs can be configured via +URAT command, by default 4G-3G-2G in decreasing priority order.

Before changing the RAT settings with the +URAT AT command, set the module to minimum functionality (via the AT+CFUN=0 command). To make the setting effective, set the module to full functionality (via the AT+CFUN=1 command). Table 11 shows an example of the procedure.

Command	Response	Description
`AT+URAT?`	`+URAT: 2` `OK`	Query the currently set RAT. Currently selected RAT is UMTS.
`AT+CFUN=0`	`OK`	Set the modem to minimum functionality.
`AT+URAT=3,2`	`OK`	Change RAT selection to LTE, UMTS (high priority LTE).
`AT+URAT?`	`+URAT: 3,2` `OK`	Query the currently set RAT. Currently selected RAT is LTE, UMTS (high priority LTE).
`AT+CFUN=1`	`OK`	Set the modem to full functionality.

Table 11: example of RAT configuration

The module can scan over several bands to find a network to attach to. The host application can limit the scanning to specific bands to shorten the time to find a network e.g., for testing purposes.

Use the +UBANDMASK AT command to specify these bands as an 8-byte bitmask. In the bitmask, for LTE RAT the bit at (band-x) position enables (if 1) or disables (if 0) the scan of the band. For legacy RATs, the bit interpretation is provided in LARA-R6 series AT commands manual [1].

Some examples are depicted in Table 12 and Table 13.

Bands	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1		
Base 2	2^{27}	2^{26}	2^{25}	2^{24}	2^{23}	2^{22}	2^{21}	2^{20}	2^{19}	2^{18}	2^{17}	2^{16}	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	Sum	Bitmask
Enable B20	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2^{19}	524288
Enable B2, B4, B5, B12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	**1**	**1**	0	**1**	0	$2^{19}+2^{4}+2^{3}+2^{1}$	2074
Enable B4, B13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	**1**	0	0	0	$2^{12}+2^{3}$	4104

Table 12: +UBANDMASK LTE bitmask creation examples

Command	Response	Description
AT+UBANDMASK?	+UBANDMASK: 3,2061752998111, 0,2,562950035734912 OK	Query the currently set bands. Currently selected bands are: • LTE bands: 1, 2, 3, 4, 5, 7, 8, 12, 13, 18, 19, 20, 26, 28, 38, 39, 40, 41 • UMTS: 1,2,5,8 • GSM: DCS1800, EGSM900, 850, PCS1900

Table 13: +UBANDMASK AT command example

7.1.2 PLMN and RAT selection rules

SIM card configuration can overrule +URAT settings: in automatic PLMN selection mode (+COPS: 0), the +CPOL lists of PLMNs have higher precedence with respect to a visitor PLMN not present in such list, so a higher priority 2G or 3G PLMN can be reselected from a roaming PLMN with lower priority even if the module is currently registered on it in LTE. In national roaming, the HPLMN will be looked for with the same procedure, periodically or when performing a AT+COPS=2/AT+COPS=0 cycles.

To assess the current SIM configuration and PLMN and selection rules, the following commands can be issued:

Command	Response	Description
AT+CIMI	123010123456063 OK	Query the IMSI, whose first 5-6 digits (define the HPLMN, 123-01 in this case.
AT+CRSM=176,28633,0,0,0	+CRSM: 144,0,"FFFFFFFFFFFFFFFFFFFF FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF FFFFFFFF" OK	Check if Equivalent HPLMN file is present in SIM card.
AT+CPLS=1	OK	Select operator preferred PLMN.
AT+CPOL?	+CPOL: 1,2,"32101",1,0,1,1 +CPOL: 2,2,"43201",1,0,1,1 +CPOL: 3,2,"54301",1,0,1,1 OK	List of operator higher priority PLMN available in SIM card. If some entry with the same MCC as current registered PLMN is available, and the PLMN has higher priority or the current VPLMN is not present in SIM card, high priority PLMN scan will be triggered.
AT+CPLS=0	OK	Select user preferred PLMN.
AT+CPOL?	OK	List of user higher priority PLMN currently configured in SIM card, empty in the example. The file might be not present in the SIM card.

Command	Response	Description
AT+CEREG?;+CREG?;+CGREG?	+CEREG: 0,5 +CREG: 0,5 +CGREG: 0,4 OK	Module is in roaming in LTE. In case current VPLMN is equivalent to the HPLMN, +CEREG/+CREG/+CGREG read commands would return 1.
AT+COPS?	+COPS: 0,2,"32102",7 OK	The current VPLMN is lower priority than high priority.
AT+CPOL=1,2,"32102",1,0,1,1	OK	User can edit to the user high priority PLMN list, so that the current VPLMN is treated as high priority.

Table 14: example of how to check and edit the SIM PLMN preferences

☞ To know the RAT, use +CREG/+CGREG commands for 2G/3G, and +CREG/+CEREG for 4G.

7.1.3 PLMN selection at startup

The last registered PLMN stored in LOCI files (CS/PS/EPS LOCI EF in SIM card, EPS can be stored in NVM if SIM card does not contain the file) will be selected at registration cycles (e.g., AT+CFUN=0/1).

To trigger search of HPLMN at registration cycle, LOCI files shall be cleaned with +CSIM command (EPS LOCI info in NVM cannot be cleaned), or AT+COPS=0 shall be used to trigger higher priority PLMN scan.

If 2G/3G RAT has been reselected due to LTE coverage limitations, LTE will be reselected due to cell's RAT priority configuration (LTE has usually higher priority) but **only if the module is in idle mode state** (opposite to connected).

☞ AT+CFUN=0/1 can be used to trigger a registration cycle with switch-off detach (which does not need the DETACH_ACCEPT message from the network). A detach of type normal can be obtained with the AT+CGATT=0 command for testing purposes.

☞ The AT+COPS=2/0 cycle triggers a high priority PLMN scan, so this cycle shall be avoided in roaming conditions if the goal is to restart the cellular modem functionality e.g., after a prolonged error condition.

☞ On multi-RAT modules, AT+COPS=1,2,"<PLMN>",<RAT> forces a single RAT behavior. It can be used followed by AT+COPS=0 command to restore previous settings.

7.2 Network attach and PDN connections

Depending on the RAT adopted in the attach procedure, different considerations need to be made.

LTE technology is "always on", so an IP address is always assigned to the initial default EPS bearer, which is activated during the LTE registration procedure, defined on <cid>=1 and usually devoted to data/Internet connectivity.

Differently, in 2G and 3G (legacy RATs), the IP address is maintained if 2G/3G is reselected from LTE, while it is assigned during a PDP context activation, which needs to be manually triggered via the AT+CGACT=1,<cid> (usually <cid>=1) command.

☞ PDN connections shall be manually reactivated if deactivated due to mobility or to a network detach.

☞ Be aware that in 2G/3G no PDP context is activated automatically, so if an application activates a PDP context on a <cid> other than 1, then if the module moves to LTE, then the initial default EPS bearer will be that one, therefore it is recommended to activate the PDP context for data always

starting from <cid>=1, in this way when changing RAT from legacy ones to LTE, then the initial default EPS bearer will be always on <cid>=1.

In general, given that IP embedded applications (such as BIP, security client, or LwM2M) may activate the Internet PDP context and de-activate it after usage without synchronization with the user application that shares the same PDN connection, it is advisable to always activate it with AT+CGACT=1,<cid> before usage to “reserve” the packet data connectivity service.

☞ If the uFOTA is enabled and needs to contact the uFOTA server when running on 2G RAT, the LwM2M will automatically activate the default context. The same concept is applicable to the security client.

☞ In case of “reserving” the packet data connectivity service, the AT+CGACT=1,<cid> command will return the OK final result code, even if the +CGDCONT AT command reports that the context is already active with a valid IP address.

If necessary, it is possible to activate more than one PDN connection with different APN at the same time in the module. This configuration is useful for applications that require to use simultaneously two or more different APN addresses.

☞ Such configuration with multiple APN addresses requires permission and configurations from the MNO and SIM card provider.

7.2.1 PDN settings (APN name and PDP type)

To change the PDN settings for the initial default EPS bearer established during LTE attach, edit the <cid>=1 PDN by means of the +CGDCONT AT command, as shown in Table 15.

Command	Response	Description
AT+CFUN=0	OK	Turn off the modem radio so to de-register the module.
AT+CEREG=2;+CGEREP=2,1	OK	Enable a set of registration URCs.
AT+CGDCONT?	+CGDCONT: 1,"IPV4V6","","0.0.0.0 0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0",0,0,0,2,0,0,0,0,0,0 OK	Read IP type and APN for EPS attach bearer.
AT+CGDCONT=1,"IPV4V6","custom_APN"	OK	Set APN name ("custom_APN" for example) and the PDP type ("IPV4V6" for example) for EPS attach bearer.
AT+CFUN=1	OK +CEREG: 1,"0001","01a2d001",7 +CGEV: ME PDN ACT 1	Turn on the modem radio. URCs indicate the registration status change.

Table 15: Change of PDN settings

For additional details on the PDN connection topic, see the LARA-R6 Internet applications development guide application note [7].

☞ After PDN activation the AT+CGDCONT and AT+CGDCONTRDP read commands return the user-configured APN, not the one assigned by the network.

7.2.1.1 PDN connections in Verizon profile (+UMNOPROF:3)

In Verizon HPLMN (for both data-only and VoLTE capable devices), and in roaming (for VoLTE capable devices):

- <cid>=1 is reserved for IMS (APN class 1).
- Internet PDN connection is mapped to CID= 3 (APN class 3) and shall be manually activated with AT+CGACT=1,3.

- Dialup connection shall be performed with ATD*99***3#.

In roaming, for data-only devices:

- IMS client is turned off.
- <cid>=3 (APN class 3) is automatically activated at network attach phase, IPv4-only. No IPv6 connectivity is granted.
- Dialup connection shall be performed with ATD*99***3#.

7.2.2 LTE attach type

All profiles use Combined Attach (CS & PS); if successful, both data and SMS (for data-only modules) or SMS/CSFB (for voice capable multi-RAT modules) services are allowed. If LTE attach is successful for EPS-only services, voice services are still possible via IMS/VoLTE and SMS can be supported via IMS client: the latter is the typical behavior in the Verizon profile.

In the Attach Request message, the module declares itself as voice-centric or data-centric.

7.2.3 Authentication settings

If PAP or CHAP authentication is to be configured, the +UAUTHREQ AT command shall be used. If the authentication is required on the initial default bearer, the setting shall be entered in de-registered state.

7.3 Voice and data services

7.3.1 Voice capable devices

In LTE, speech calls are supported via the IP based IMS protocol (VoLTE). LTE only VoLTE capable devices are configured as “data centric” because voice services are performed only via IP. Voice capable multi-RAT devices are configured as “voice centric” in global profile (+UMNOPROF: 90), as “data centric” in AT&T profile (+UMNOPROF: 2).

In 2G, voice calls and data transfer cannot run in parallel, due to GSM/GPRS technology limitations. Data is suspended while speech calls (and SMS, which are very quick) are performed.

7.3.1.1 CSFB

If IMS services are not supported by SIM card subscription or by the current PLMN (VoIP flag is indicated at PDN connection establishment), on multi-RAT devices speech calls are carried out via CSFB (Circuit Switched Fall Back) to legacy RAT.

CSFB is a redirection to a 2G or 3G cell, where CS/PS registration is performed, then a traditional speech call is started, at whose end the module automatically reselects back the LTE cell: the change of RAT, the cell selection and the registration procedure at RAT change overall imply longer call setup delays (up to 20 s) compared to VoLTE calls or calls started while already in 2G and 3G.

7.3.1.2 3G sunset

3G is at sunset, therefore networks might have only LTE, in which cases CSFB will not be allowed. If VoLTE is not supported by the SIM or by the roaming PLMN, the voice capable module configured by default as “voice centric” will reselect a legacy RAT to be able to access speech call service. This might cause long lasting out of service periods if the current PLMN has no cells in legacy RAT.

Host applications can use +USVCDOMAIN to select “data centric” UE usage settings and avoid reselection to legacy RAT if the user is using a voice capable device but wants to give preference to data on LTE.

The host application can use the +CIREG AT command to check IMS registration status; it can use +CEREG and +CREG to check if CSFB is allowed in current PLMN; such information can be used to take countermeasures e.g., change UE usage settings to “data centric” or to handle LTE temporary disabling due to voice centric setting in a controlled manner.

7.3.2 Data-only modules

Data-only LARA-R6 modules do not support speech call service. In particular, in LTE no VoLTE nor CSFB (in multi-RAT modules) is possible: LTE attach type is "combined EPS/non EPS" and additional attach type "SMS only". Data-only modules in global MNO profile +UMNOPROF: 90 present themselves as "data centric, PS voice only" instead of "SMS only" to prevent Interoperability issues with some network vendors which strictly require this encoding; if the network does not grant SMS service during LTE attach, after 5 TAU attempt cycles +CREG: 3 (CS registration denied) is returned.

Despite in 2G/3G +CREG and +CGREG returns CS and PS normal service registration status, dial command ATD123; immediately returns NO CARRIER and mobile terminated calls are automatically disconnected by the device with appropriate error cause in NAS signaling.

7.4 Radio Policy Manager

LARA-R6 series modules implement the Radio Policy Manager (RPM) feature according to GSMA connection efficiency TS 34 RPM [18] aims to prevent cellular devices to aggressively try registration or PDP context activation procedures in case of permanent failures (e.g., “invalid UE” or “EPS services not allowed”), which are usually due to subscription restrictions, in addition to standard 3GPP retry algorithms. Since these aggressive behaviors can cause network overload and service outage, some MNOs require to have RPM active by default; RPM can be enabled via AT commands (AT+URPM=1) on other MNOs requiring it.

Even if RPM is not active, it is recommended to limit the number of registration and power cycles per hour (20 at most is a good rule of thumb) to avoid network unfriendly behaviors.

7.5 Mobility scenarios

Devices used in non-static installations can move out of range of the currently serving cell. This means entering another cell of the RPLMN (registered PLMN) or of a different PLMN or moving into an area where there is no cellular coverage or no roaming agreement for the device.

If the module loses the synchronization with the serving cell but finds another cell to camp on, any PDP context and open sockets will be kept. This holds in particular for seamless change of serving cell with cell reselection or handover procedures, even changing RAT.

If mobility implies crossing national borders or simply changing the PLMN, it is likely that the new PLMN will force the module to reattach; if the selected cell belongs to a legacy RAT, it is necessary to re-establish the PDP context in order to restore the services requiring cellular connectivity.

If in roaming conditions there is a PLMN with higher priority than the currently selected PLMN (see +CPOL), the module periodically performs a PLMN scan when in RRC idle state.

7.5.1 RRC procedures in mobility

RRC procedures are different depending on the current RAT of the radio connection and the service domain:

- In LTE, the UE is instructed by the network to provide measurement reports on neighbor cells so that the network can decide if and when the radio resource control (RRC) connection has to be handed over to another cell via RRC Connection Reconfiguration message.

  - The network will allocate gaps in the downlink transmission to allow the device to perform the intra-band or inter-band measurements
  - Inter-RAT HO is supported towards 3G
  - +CSCON will return the status of the RRC connection
- In 3G, depending on the logical channels assigned to the UE, the module is ordered to perform hard handover or soft handover (TX or RX paths from cells of the so called “active set” are recombined for optimal performance); the UE can be in the following states (see +UCGED)
  - In RRC connected mode in HSPA (High Speed Packet Access Channel) for PS data transmission at high rate
  - In RRC connected mode in DCH (dedicated channel), where soft HO usually used
  - In RRC connected mode in RACH/FACH or cell-PCH/URA-PCH states
  - In RRC idle mode
  - To release the RRC connection in case the host application has no more data to send out, Fast Dormancy feature can be activated via the +CNMPS AT command.
- In 2G the UE is assigned CS channels (for speech calls or SMS), where handover is supported for call continuity, or GPRS/EGPRS channels, where handover is not supported and autonomous or NW ordered cell reselection is performed at cell change, with possible loss of data.

7.6 Deep-sleep mode, PSM and eDRX

LARA-R6 "01B" product version modules support the 3GPP power saving features PSM and eDRX as well as deep-sleep mode. PSM and eDRX are disabled by default and can be enabled on LTE RAT, both separately or simultaneously. eDRX is also supported on "00B" product version.

PSM comes with PSM deep-sleep option enabled, i.e. the minimum functionality deep-sleep mode is periodically accessed during PSM cycles. Temporary prevention of deep sleep entrance is supported via +UPSMVER AT command. Deep-sleep entrance during eDRX cycle and in out of service condition is not supported.

PSM deep-sleep can be used only when the AT interface is accessed via the UART; USB diagnostic port can be used and will not alter deep-sleep entrance timings.

PSM can be used only in data-only products with IMS client disabled.

See the SARA-R422 / LEXI R422 application development guide [19] for further details about deep-sleep mode, PSM and eDRX. See LARA-R6 series AT commands manual [2] to check the supported AT commands and default PSM and eDRX values.

8 Monitoring module status

The module registration status can be retrieved by using the following URCs:

- **+CREG** works for all RATs; it monitors the CS status;
- **+CGREG** monitors the PS status (RAT=2G or 3G);
- **+CEREG** monitors the EPS network registration status (RAT=4G);

It is recommended to enable +CREG and +CEREG URCs with <n>=3, because in this way information about the cause of rejection is reported when registration is rejected by the network.

Using a logical OR between these URCs to know all registration statuses.

The **+UCGED** AT command can be used to retrieve information details on the current cell where the module is registered.

The IMS client registration status can be retrieved with the following URC:

- **+CIREG** monitors the IMS status registration (RAT=4G)

The **+CGEV** URC, enabled via +CGEREP, provides information about the PDP context status.

On LARA-R6 series the +CGATT read command is equivalent to the +COPS read command. In fact it returns +CGATT: 0 in out of coverage (OoC) scenarios (even if no detach has occurred).

Similarly, the URC '+CGEV: ME DETACH' reports the OoC condition, in particular when caused by a radio link failure.

8.1 Retrieve and interpret diagnostic information

It is recommended to track the module status in the host application. Such diagnostic information allows detection of specific scenarios and implementation of proper handling and countermeasures in the host application.

The module status can be returned by AT command responses and unsolicited result codes (URCs). Depending on the host application architecture, URCs, periodic polling, or both, can be used. URCs provide the most updated information and, in some cases, diagnostic information which is not available via polling. For AT commands that enable URCs, they might also return the same information when polled, as indicated below.

Some commands store the setting of the URC reporting in NVM, so they are referred to as persistent settings.

Some AT commands provide a choice on how to handle the URCs when the AT interface is busy; for all other AT commands, URC is issued at the return into command mode, as explained in LARA-R6 series AT command manual [1], in the "URCs presentation deferring" section.

URCs and AT command responses are presented with their generic syntax because parameters names are quite explanatory; for precise meaning, see the LARA-R6 series AT command manual [1].

8.1.1 Diagnostic information via URCs

Command	URC	Description	Can be polled
AT+CSCON=1	+CSCON: 1	In LTE, it returns the status of the RRC connection (idle or connected). Persistent setting.	Yes
AT+CREG=2	+CREG: <stat>[,[<lac>],[<ci>][,[<AcTStatus>]]]	Enable registration status URC for CS services in legacy RAT/ non-EPS services (for example, SMS) in LTE	Yes
AT+CEREG=3	+CEREG: <stat>[,[<tac>],[<ci>],[<AcT>][,[<cause_type>],[<reject_cause>]]]]	Enable registration status URC for EPS services, reject cause in case of unavailability of such services	Yes
AT+CGEREP=2,1	+CGEV: NW PDN DEACT <cid>	Report all registration and PDN connectivity status events. The first parameter of the AT command is set to 2 indicate that URC will not be discarded in case the AT interface is busy. The URC in the example is reported when the device enters out of coverage condition, in particular after a radio link failure	No
AT+CTZR=1	+CTZV: <tz>	Enable reporting of changes in time zone. Usually, time zone information is provided by the network at LTE attach only.	No
AT+CMER=1,0,0,2,1	+CIEV: <descr>,<value>	Report variations in some indicators like roaming, SIM indication (provided that the feature is configured via +UGPIOC), signal level.	No
AT+CNMI=2,1	+CMTI: <mem>,<index>	Report the index in current selected memory (can be the factory-programmed setting ME or SIM, see +CPMS read command) where the mobile terminated SMS has been stored. The first parameter set to 2 indicates that URC are buffered in case of busy AT interface. The setting is volatile and shall be re-entered at every switch on.	No
AT+UCUSATA=4	+UUSIMSTAT: <state>	+UCUSATA enables +UUSIMSTAT URC of SIM REFRESH events, which might indicate the change of some operational parameters in the UICC card (for example, IMSI swap, SIM profile installation after remote SIM provisioning). The setting is persistent.	No
AT+UBIP=1	+UUBIP: <ev_cmd>,<val>	URC are raised when Open Channel, Close Channel, Send Data, Receive Data and Channel status events are issued by the SIM card towards the device to handle a SIM OTA session, for example for remote SIM provisioning. The embedded BIP client will cater for establishing the required socket and exchange data with the SIM OTA server. The setting is persistent.	No
AT+UFOTASTAT=1	+UFOTASTAT: <event>,<param1>[,<param2>]	Provide information on the progress and outcome of the Firmware download over the air via LwM2M (uFOTA). The setting is persistent.	No
AT+ULWM2MSTAT=1	+ULWM2MSTAT: <event>,<param1>[,<param2>]	Enable URC to report the activity of the embedded LwM2M client. The setting is persistent.	No

Table 16: Diagnostic information via URCs

☞ Always consider configuring the +CGEREP AT command with <mode>=2 to avoid losing URCs when the AT interface is busy executing some other AT commands.

8.1.2 Diagnostic information via polling

Command	Response (omitting OK)	Description	Suggested usage
ATI ATI9	LARA-R6001D-00B-00 00.13,A00.01	Return the model and FW identification, useful for tracking purposes.	Module initialization
AT+CGSN	358110420002839	Return the IMEI.	Module initialization
AT+CIMI AT+CCID	001010123456789 +CCID: 89860000502000180722	Return the SIM identities for tracking purposes. They can change after a SIM refresh event that can be reported by +UUSIMSTAT URC.	Module initialization
AT+UBANDMASK?	+UBANDMASK: 3,2061752998111,0,2,562950035734912	Return band mask selection. Check specific syntax on AT command manual.	Module initialization
AT+UMNOPROF?	+UMNOPROF: 90	Return MNO profile set.	Module initialization
AT+UCGED?	+UCGED: 2 6,<svc>,<MCC>,<MNC><EARFCN>,<Lband>,<ul_BW>,<dl_BW>,<TAC>,<LcellId>,<P-CID>,<mTmsi>,<mmeGrId>,<mmeCode>,<RSRP>,<RSRQ>,<Lsinr>,<Lrrc>,<RI>,<CQI>,<avg_rsrp>,<totalPuschPwr>,<avgPucchPwr>,<drx>,<l2w>,<volte_mode>[,<meas_gap>,<tti_bundling>	Return several cell parameters as measured by the module or provided by the network. Some values like CQI and signal indicators are periodically refreshed in the module on a 0.5 s base, so the application should average them. Useful when the module seems not registered as, in combination with +CESQ, can show current cell.	Low periodicity
AT+CESQ?	+CESQ: <rxlev>,<ber>,<rscp>,<ecn0>,<rsrq>,<rsrp>	Return signal quality and level, and it is more precise than +CSQ. It is subjected to transitions due to local reset of values at changes in RRC state (idle, connected) so the host application should average the values.	Periodically (for example, every 50 to 10 s)
AT+COPS?	+COPS: <mode>[,<format>,<oper>[,<AcT>]]	It returns the current registered PLMN in the configured format, RAT is fixed to 7 (LTE).	Periodically (30 s) and when detecting problems
AT+CGATT?	+CGATT: 0	Like AT+COPS?, it returns 0 when the module enters out of coverage, despite no PS detach has occurred and PS service is just suspended.	Periodically (20 s) and when detecting problems
AT+CGDCONT?	+CGDCONT: <cid>,<PDP_type>,<APN>,<PDP_addr>,<d_comp>,<h_comp>[,<IPv4AddrAlloc>,<request_type>,<P-CSCF_discovery>,<IM_CN_Signalling_Flag_Ind>[,<NSLPI>[,<secure_PCO>[,<IPv4_MTU_discovery>[,<Local_Addr_Ind>]]]]]	It returns the active and defined EPS bearers with the APN used and the IP type and addresses.	Periodically (30 s) and when detecting problems
AT+CPOL?	+CPOL: <index1>,<format>,<oper1>[,<GSM_AcT1>,<GSM_Compact_AcT1>,<UTRAN_AcT1>[,<E-UTRAN_AcT>]]	It returns the high priority PLMN list, which might change at SIM refresh. Check it both in AT+CPLS=0 and AT+CPLS=1	Module initialization and SIM refresh, only in debug/test mode

Table 17: diagnostic information via polling

8.2 Full-stack watchdog: how to react to unexpected conditions

The application shall properly handle communication or connectivity problems that can arise when using the module in the cellular mobile environment.

When a problem at a specific level is encountered, the countermeasure for that level should be tried and, if that does not resolve the issue, then proceed with the solutions for the lower levels. Table 18 shows a full-stack watchdog for monitoring LARA-R6 series modules.

Level	Problem	Countermeasure	AT commands / actions	Notes

Socket/dial-up	Cannot send/receive data	Close and re-open socket	`AT+USOCL=<socket_id>`
			`AT+USOCR=<protocol>`
			`AT+USOCO=…`	

		Disconnect and re-connect dial-up	Send `+++` / Move DTR `ATD*99***<cid>#`	
IP/PDP	Cannot get an IP address; cannot establish dial-up	Detach/re-attach	`AT+CFUN=0` `AT+CFUN=1`	Consider possible restrictions to multiple <cid>s active for APN. If IPv6-only PDN is set in Verizon Wireless MNO setting, detach/deactivation may be caused by failing IPv6 acquire by SLAAC. The retry is managed automatically based on VZW Data Retry logic.
		Deactivate/re-activate context (<cid> != 1)	`AT+CGACT=0,<cid>` `AT+CGACT=1,<cid>`	
Network registration	Cannot register	Detach/re-attach	`AT+CFUN=0` `AT+CFUN=1`	AT+CFUN=0/1 must be preferred for registration cycles. Moreover AT+CFUN=0/1 is faster than AT+COPS=2/0.
RF	Cannot register	Disable/re-enable RF functionality	`AT+CFUN=0` `AT+CFUN=1`	AT+CFUN=4 is NVM persistent, better to use AT+CFUN=0.
Module FW	Cannot register	Soft reset	`AT+CFUN=15`	
AT interface	No response from module	HW switch off	GPIO power control	See the LARA-R6 series system integration manual [4] for details and alternatives.

Table 18: Full-stack watchdog for LARA-R6 series modules

9 SIM

9.1 SIM communication

Module and SIM card communicate through a serial interface. The module automatically starts a communication with the SIM at boot for cellular protocol stack operations. The host application can interact with applets and services residing in the SIM card using a set of AT commands. Based on capabilities these commands can be divided in two groups:

- commands for restricted access
- commands for generic access

9.1.1 Commands for restricted access

Commands for restricted access are a set of high-level commands that allow simple but limited interactions with the SIM and its contents. The handling of all the steps required by communication protocol used by module - SIM interface is managed internally by the module, and therefore not a concern for the host application.

This subset includes the +CRSM and +CRLA AT commands.

9.1.1.1 Examples of UICC communication

Below are examples of commands for restricted access.

Command	Response	Description
Read IMSI (International Mobile Subscriber Identity)		
AT+CRSM=176,28423,0,0,0	+CRSM: 144,0,"082922107840836055" OK	Read the IMSI using the Restricted SIM access command. • 176 is the read command for EF in binary format. • 28423 is the ID for EF_IMSI, the SIM elementary file where IMSI is stored by SIM manufacturer. The <response> parameter in +CRSM answer contains few prefix bytes followed by the IMSI value with swapped nibbles.
AT+CIMI	222018704380655 OK	Read the IMSI. The response is the readable serial number. This example is for reference only, as an alternative AT command to read IMSI.
LOCI management		
AT+CRSM=176,28542,0,0,0	+CRSM: 144,0,"623C50A322F210D5BD0000" OK	Read EF_LOCI, the SIM elementary file where information about last CS location is stored
AT+CRSM=214,28542,0,0,11,"FFFFFFFFFFFFFFFFFFFFFF"	+CRSM: 144,0,"" OK	Erase EF_LOCI content. This command is useful to start a registration procedure from scratch. For this scope, the below EF shall have to be erased as well: • EF_PSLOCI (28531) • EF_EPSLOCI (28643)
Read emergency call codes		
AT+CRSM=178,28599,1,4,0	+CRSM: 144,0,"11F2FFFFFFFFFFFFFFFFFFFFFFFFFFFFFF01" OK	Read the list of Emergency Call numbers stored in the SIM by MNO. 178 is the read command for EF in record format.

9.1.2 Commands for generic access

Commands for generic access are a subset of low-level commands that allow the direct control of messages sent to the SIM and received from it; the full knowledge of APDU protocol syntax and procedures is therefore needed.

This subset includes the +CSIM and +CGLA AT commands.

9.1.3 SIM logical channels

The exchange of messages (APDU) between SIM card and module occurs through "logical channels" that work on the physical SIM serial interface.

9.1.3.1 Basic logical channel

At module boot, the “basic logical channel” (logical channel 0) is automatically opened, and it is used for cellular protocol stack operations.

This channel is owned by the module, and the host application is not allowed to close it. For the same reason, internal module commands have the priority, and AT commands that do not coordinate (e.g., +CSIM) will not disrupt the module functionality but might be disturbed by the module.

9.1.3.2 Supplementary logical channels

To allow interactions with applets and services residing in the SIM card, cellular SIM cards support supplementary logical channels (up to 3).

These channels shall be explicitly activated by the module and the SIM card assigns them a progressive number from 1 to 3. The user or host application can manage logical channels using proper AT commands. It is recommended to use an independent supplementary channel for each different applet/service and to close them at the end for reuse.

In LARA-R6 modules, in addition to logical channels 0 the module automatically activates logical channel 1 as well. Its usage by user / host application is allowed. Since some SIM applications (e.g., ISD-R) cannot have multiple parallel sessions, they should be selected on the channel intended for them and in these cases the usage of logical channel 1 could be mandatory.

Command	Response	Description
Generic SIM access		
AT+CSIM=10,"0070000000"	+CSIM: 6,"029000" OK	Open a new supplementary logical channel. As per ISO/IEC 7816-4, <response> parameter contains • the number assigned to the opened channel: “02”. This means that channel “01” is already active • the action result: “9000” (means ‘Command successfully executed’)
AT+CSIM=10,"0270800200"	+CSIM: 4,"9000" OK	Close the supplementary ch2 (indicated in the 4th byte), using the same ch (indicated in the 1st byte)

9.2 Chip SIM

For devices utilizing a physically soldered-down chip SIM, consider what network or networks the device will connect to. More specifically, beyond the obvious intended end network(s) the device will deploy on, keep in mind the need to connect with a test network or base station simulator call-boxes, which may require a specific UICC profile to connect to. Anticipate such needs and be prepared to be able to obtain and configure a profile to connect to such networks or simulators.

Alternatively, here below some other possible ways to proceed for testing purposes:

- Configure a device(s) with a SIM card holder for physical removable SIM for such engineering or pre-production activities.
- Make sure to disable authentication and integrity checks on the tester side (by proper setting) and, for LTE and 3G (for 2G it is not required), on the module (by using the AT+UDCONF=81,0 AT command, see LARA-R6 series AT commands manual [1]).

10 SMS

10.1 Preferred message storage

The factory-programmed value for LARA-R6 & LARA-L6 series modules is "ME" for the three memory parameters <mem1>, <mem2> and <mem3>. The setting can be set or read by the +CPMS AT command.

This is an example regarding the configuration of the +CPMS storage parameter for all memory parameters to the same value.

Command	Response	Description
`AT+CPMS="ME","ME","ME"`	`+CPMS: 0,255,0,255,0,255` `OK`	Set all three memory storage parameters to “ME” memory storage.
`AT+CPMS?`	`+CPMS: "ME",0,255,"ME",0,255,"ME",0,255` `OK`	Read the storage setting back.

Table 19: preferred message storage

For more details on the +CPMS AT command, see LARA-R6 / LARA-L6 series AT commands manual [1].

11 EFS backup & restore

Due to the nature of flash memory, the embedded file system (EFS) may incur memory corruption if the safe & graceful shutdown procedure outlined in the LARA-R6 & LARA-L6 series system integration manual [4] is not followed. It is possible that memory corruption may result in the device being inoperable or may impact specific device data information.

For a fatal memory corruption, the EFS backup & restore feature allows the module to autonomously restore the EFS using the last EFS backup stored on the module itself.

Backup of device's unique parameters (like for example RF calibration data, IMEI, etc.) is performed at the u-blox factory and is stored on the module as the first backup copy for the device. The host application has the option to make subsequent backups to supersede the previous backup copy. If an EFS corruption is detected, then the restore is triggered autonomously at the device boot-up process to restore the device with the single backup copy stored on the device.

Backup & restore is a unique feature that may extend the lifetime of the modules in the field.

⚠ It is critical that the host application follows the proper safe and graceful shutdown procedure outlined in the LARA-R6 series system integration manual [4]. The backup & restore feature is intended only as an additional backup mechanism if, on the potential rare occasion, the host application shutdown does not conform to the graceful power-down guidelines.

11.1 Description

There are two parts to the EFS backup & restore feature for LARA-R6 & LARA-L6 series modules.

First, the restore function allows a module to automatically recover from a fatal file system corruption if it should detect such a corruption from a previous improper shutdown at the next module boot-up. If the corruption is non-fatal, and the module can boot up, then the host can manually trigger a restore.

These non-fatal corruption types are considered:

- MNO profiles lost or duplicated
- Device goes into the non-signaling mode (for more details, see +UTEST AT command)

☞ A restore should be host triggered only in one of the above conditions.

The second part of this feature is optional for a device that comes with this feature from the factory, where the host can perform a backup of the file system to supersede the previous or original backup done during the module production. This will allow the latest user values in the file system to be captured in the backup copy. The table below lists how different data are handled during backup.

Item	LARA-R6001D	LARA-R6401D	All other LARA-R6/L6 product versions
Personalization data for security, calibrations, and unique data	Restored.	Restored.	Restored.
Files in user file system	Not considered.	Not considered.	Not considered.
MNO profiles	Back to the factory programmed settings.	Back to the factory programmed settings.	Restored.
User NVM settings (i.e. +UBANDMASK)	Back to the factory programmed settings.	Restored.	Restored.
User certificate and private keys	Restored.	Restored.	Restored.

11.1.1 EFS backup

The EFS backup can be initiated with the +UBKUPDATA AT command and will automatically trigger a backup process upon receiving the command. After this procedure is completed, the device will store status information that can be queried with an AT command. After the backup completion, no further action is required.

The host can initiate a backup on an infrequent and rare basis when there is a justified need to perform a backup. This could be when some important and significant information in the file system has changed or been added via AT commands, e.g., regarding the personalization data for security. One likely instance requiring a backup is after the host application factory initial "production", which may include the module configuration to a specific use case requirement related to the security functionalities. The backup command can also provide some information about the last backup.

The command's query response contains the number of backups and restores for each file system.

⚠ To avoid excessive flash wear, the backup should be performed on a limited basis such as after host application production and initialization.

☞ There are not multiple backup “versions” stored; only a single copy of the latest backup is kept.

☞ It can take up to 15 s for a backup to execute.

The host can detect when the backup is complete, and the AT interface is available by a URC notification. Example: the **+UUBKUPDATA: 2,1** URC indicates the backup has successfully taken place.

11.1.2 EFS restore

When an automatic restore is triggered, the device will immediately reset/restore the file system (this may interrupt any currently running processes). The device will then reset, and store status information that can be queried with an AT command. After the restore procedure is completed, no further action is required, although some settings may need to be restored manually by the user, if they were modified since the last backup.

If the restore process is interrupted (e.g., through power pull), the process will start from the beginning again at the next module boot-up.

There is no available indication to the host processor that a restore is taking place during boot-up; it would just appear as if boot-up is taking longer than usual. If a restore should take place, then the host processor would need to allow more time for the device to handle the restore, until the AT interface is made available.

☞ It can take up to 15 s for a restore to execute. This time includes the boot-up time.

The host can detect when a restore has taken place by a URC notification. Example: the **+UUBKUPDATA: 2,1** URC indicates the restore has taken place and is successful.

A manual restore can be triggered when one of the following conditions is detected by the host:

- MNO profiles lost or duplicated, which can be checked and detected with +UMNOPROF AT command
- The device goes into the non-signaling mode and is unable to exit with AT+UTEST=0 and +CFUN cannot change its state from a value of 5. This non-signaling state can be checked and detected with the +CFUN read command, where the device would return a value of 5.

Restore is only intended for the above situations.

With the possibility of a restore event, to detect when the module boot-up is complete and the AT interface is available, here are following options:

- Loop AT until the "OK" final result code is issued
  - Example: send AT every one second until the OK final result code is received
- Enable and monitor the GPIO pin with “Module status indication” functionality via the +UGPIOC AT command
- Enable and monitor the greeting message via the +CGST AT command

11.1.3 Creating backup after flashing FW update with delta package

If a FW build with the backup & restore feature is being updated via FOTA / uFOTA with a delta package, then after the successful update a backup is triggered autonomously by the module itself.

11.1.4 EasyFlash, backup and SMS storage

If a FW build with the backup & restore feature is being flashed onto a module via EasyFlash, after a successful FW update when the device boots up, then the host is required to:

- set the preferred SMS message storage with the +CPMS AT command just once after flashing. This step is required if the host application should use SMS. If it does not intend to use SMS, then this step can be ignored. Even if the host intends to use the +CPMS factory-programmed setting, the storage setting still needs to be set.

11.1.5 Backup & restore of secure storage

Secure storage is used to keep security critical data. The secure storage backup/restore functionality is used in cases when the secure storage is corrupted because of an EFS corruption.

To observe the secure storage corruption the following AT commands can be used:

Command	Response	Description
`AT+USECROTUID`	`+CME ERROR: SEC RoT not personalized`	Error result code indicates secure storage corruption.

Table 20: storage corruption example

In case of secure storage corruption, the following AT commands need to be executed:

Command	Response	Description
`AT+USECOPCMD="rotrestore",1`	`OK`	Restore the secure storage.
`AT+CFUN=15`	`OK`	Reset the device to execute the restore operation.
`AT+USECOPCMD="rotresync"`	`OK`	Resync the status of the secure storage.
`AT+CFUN=15`	`OK`	Reset the device to execute the resync operation.

Table 21: restore procedure example

12 Migration guide from LARA-R2

This list of software changes between LARA-R2 and LARA-R6 module series may help in migrating a host application between the two modules. For details of the AT commands below, see the LARA-R6 series AT commands manual [1].

Command or feature	LARA-R2	LARA-R6
3GPP Release	Rel. 9 for LTE, Rel. 9 for 3G, Rel. 9 for 2G	Rel. 10 for LTE, Rel. 8 for 3G, Rel. 9 for 2G
Local connectivity peripherals	+USIO	+USIO, +UUARTCONF
USB device class	Standard CDC-ACM	Vendor specific class (CDC-ACM like)
+UUARTCONF	n.a.	Available for AUX UART configuration
AT command execution and URC	Parallel execution on each AT interface, URC usually issues on same port where enabled	AT command processing blocked if AT command ongoing on a different interface, URC issues on all ports (+UURCONF to configure)
Modem features - SMS	SMS over IMS not enabled on VoLTE capable devices	SMS over IMS enabled on VoLTE devices
+CFUN syntax	• +CFUN: (0,1,4,6,7,8,9,15,16),(0-1)	• +CFUN: (0,1,4,10,15,16,19),(0-1) • +CFUN=19 allows to disable UICC driver
+UAUTHREQ authentication parameters configuration	Set parameters are in the following order: <username>, <password>.	The order is inverted, therefore: <password>, <username>.
MNO profile selection	• +UMNOCONF • +UMNOCONF: 3,<bitmap> allows to automatically activate <cid> associated with VZW class 3 APN	• +UMNOPROF • Default MNO profile: 90
+URAT syntax	AT+URAT=<SelectedAcTs>[, <PreferredAct>[, <2ndPreferredAct>]]	AT+URAT=<1stAcT>[,<2ndAcT>[, <3rdAcT>]]
Band configuration	+UBANDSEL	+UBANDMASK
CS/PS usage setting	+CEMODE	+USVCDOMAIN
Internet applications/Sockets	+UPSD, +UPSDA	+ CGACT and optionally +CGDCONT. Always issue the AT+CGACT=1,<cid> command on used context <cid> even if the +CGDCONT AT command returns that the context is still active with a valid IP address. This is highly recommended to activate the PS data connection avoiding possible conflicts between applications.
Cell deep scan	AT+COPS=5	+UCFSCAN
PDN sharing between dial-up and Internet applications/Socket	Not supported, dial-up has exclusive usage of PDN connection.	Supported, use +UEMBPF to reserve port range for embedded IP clients.
PPP	No constraints on DTR (virtual and physical) line to start PPP connection. LCP Configure-Request must be initialized by DCE.	DTR (virtual and physical) line must be asserted to start a PPP connection. LCP Configure-Request must be initialized by the DTE.
Device management	VZW OMA-DM on LARA-R204	LwM2M
FOTA	uFOTA via FTP, HTTP	uFOTA via LwM2M, FTP, HTTP
Cell and network diagnostic	+UCELLINFO, +CGED	+UCGED, +VZWRSRP/+VZWRSRQ (in +UMNOPROF: 3)
Call hang up	ATH	+CHUP
+UPSV (options)	+UPSV: (0,1,2,3)	+UPSV: (0,1,3)
Fast dormancy	+UFDAC	+CNMPSD
+UFACTORY	Available	Available
Security	n.a.	Supported feature: • Secure boot

Command or feature	LARA-R2	LARA-R6
		• Secure update • Anti-cloning protection • Local data protection • E2E data protection • E2E symmetric KMS
CellLocate®	Available, except LARA-R204	Available

Table 22: Software migration guide from LARA-R2 to LARA-R6 series module

13 Migration guide from TOBY-L2

This list of software changes between TOBY-L2 and LARA-L6 module series may help in migrating a host application between the two modules. For details of the AT commands below, see the LARA-L6 series AT commands manual [1].

Command or feature	TOBY-L2	LARA-L6
3GPP Release		Rel. 10 for LTE, Rel. 8 for 3G, Rel. 9 for 2G
Local connectivity peripherals	+USIO	+USIO, +UUARTCONF
USB device class	Standard CDC-ACM	CDC-ACM-QC
+UUARTCONF	n.a.	Available for AUX UART configuration
AT command execution and URC	Parallel execution on each AT interface, URC usually issues on same port where enabled	AT command processing blocked if AT command ongoing on a different interface, URC issues on all ports (+UURCONF to configure)
Modem features - SMS	SMS over IMS not enabled on VoLTE capable devices.	SMS over IMS enabled on VoLTE devices.
+CFUN syntax	• +CFUN: (0, 1, 4, 6, 9,15,16, 19, 127),(0-1)	• +CFUN: (0,1,4,10,15,16,19),(0-1) • +CFUN=19 allows to disable UICC driver
+UAUTHREQ authentication parameters configuration	• Set parameters are in the following order: <username>, <password>.	• The order is inverted. Therefore <password> goes first and then comes <username>.
MNO profile selection	• +UMNOCONF • +UMNOCONF: 3,<bitmap> allows to automatically activate <cid> associated with VZW class 3 APN	• +UMNOPROF • Default MNO profile: 90
+URAT syntax	AT+URAT=<SelectedAcTs>[, <PreferredAct>]	AT+URAT=<1stAcT>[,<2ndAcT>[, <3rdAcT>]]
Band configuration	+UBANDSEL	+UBANDMASK
CS/PS usage setting	+CEMODE	+USVCDOMAIN
Internet applications/Sockets	+UPSD, +UPSDA	+ CGACT and optionally +CGDCONT. Always issue the AT+CGACT=1,<cid> command on used context <cid> even if +CGDCONT returns that the context is still active with a valid IP address. This is highly recommended to activate the PS data connection avoiding possible conflicts between applications.
Cell deep scan	n.a.	+UCFSCAN
PDN sharing between dial-up and Internet applications/Socket		Supported, use +UEMBPF to reserve port range for embedded IP clients.
PPP	LCP Configure-Request must be initialized by DCE.	DTR (virtual and physical) line must be asserted to start a PPP connection. LCP Configure-Request must be initialized by DTE.
Device management	OMA-DM	LwM2M
FOTA	uFOTA via FTP, HTTP	uFOTA via LwM2M
Cell and network diagnostic	+CGED, +UCGED	+UCGED, +VZWRSRP/+VZWRSRQ (in +UMNOPROF: 3)
Call hang up	ATH, +CHUP	+CHUP
+UPSV (options)	+UPSV: (0,1,2,3)	+UPSV: (0,1,3)
Fast dormancy	+UFDAC	+CNMPSD
+UFACTORY	Available	Available
Security	n.a.	Supported feature: • Secure boot • Secure update

Command or feature	TOBY-L2	LARA-L6
CellLocate®	n.a.	Available

Table 23: Software migration guide from TOBY-L2 to LARA-L6 series module

Appendix

A Principal PDP context

PDP context	LARA-R6001D, LARA-R6001, LARA-R6401D, LARA-R6401, LARA-R6801	LARA-R6401D LARA-R6401 (VZW MNO Profile)	LARA-L6
Initial default bearer	CID=1	CID=1	CID=1
IMS	CID=11	CID=1	CID=11

B Cellular technology overview

The LARA-L6 / LARA-R6 series comprises multi-band and multi-mode modules supporting LTE Cat 1 FDD and LTE Cat 1 TDD radio access technology, with 3G UMTS/HSPA and 2G GSM/GPRS/EGPRS fallback, providing the ideal solution for global and multi-regional coverage.

Key applications include:

- Data transfer via tethering (dial-up)
- Data transfer via internal TCP and UDP sockets
- Data transfer via internal TCP/IP applications (FTP, HTTP, COAP, etc.)
- Speech calls via VoLTE, CSFB (circuit-switched fallback) or 2G/3G legacy speech calls
- SMS
- FW update
- Security

B.1 LTE

LTE Cat 1 is aligned to 3GPP release 10 and allows data rates up to 10 Mbit/s in downlink (DL) and up to 5 Mbit/s in uplink (UL). Full mobility is supported by intra and inter band handover. PS handover to 3G is supported too. Redirection to 2G and 3G is supported for CSFB calls. IMS client insists on LTE protocol stack for voice calls and SMS, which are also exchanged via LTE NAS (Non Access Stratum) i.e. SGs (Signaling Gateway). SRVCC (single radio voice call continuity) allows the handover of a VoLTE call to the legacy domain (2G/3G) in case of discontinuity of the LTE radio coverage. RX diversity is implemented according to related 3GPP specifications for LTE Cat 1 User Equipment.

B.2 UMTS

UMTS HSUPA/HSDPA is supported, aligned to 3GPP release 9. HSUPA Cat.6 and HSDPA Cat.8 enable data rates up to 5.76 Mbit/s in UL and 7.2 Mbit/s in DL. Fast dormancy is supported, so that RRC connection release can be requested to the network if there is no more data to send (see +CNMPSD AT command). RX diversity is supported and activated by the module in low coverage scenarios to increase sensitivity. PDP context for data transfer with its IP address is maintained when changing the RAT from LTE to UMTS on the same PLMN. Instead, they need to be manually activated if the module performs PS attach in 3G. IMS PDP context is usually disabled by the network itself when it switches to a legacy RAT, and speech calls are carried out in legacy mode, not via IMS even if the IMS PDN connection is kept active and RAT reselected. Same considerations hold for the 2G RAT.

B.3 GSM/GPRS/EGPRS

2G protocols are supported and aligned to 3GPP release 8. In GPRS multi-slot class 33 the data rate is up to 107 kbit/s DL and 85.6 kbit/s UL, while in EDGE multi-slot class 33 the data rate is up to 296 kbit/s DL and 236.8 kbit/s UL.

The GPRS/EDGE multi-slot class 33 implies a maximum of 5 slots in DL (reception), 4 slots in UL (transmission) with 6 slots in total.

SMS is supported via circuit switch domain. Although DTM (discontinuous transmission) is supported, most networks do not provide it, therefore during speech calls data services are suspended.

B.4 Circuit Switched (CS) and Packet Switched (PS)

The term circuit-switched in mobile communications refers to the switching technique used traditionally for real-time services such as voice.

With circuit-switched (CS) networks a dedicated circuit is engaged for the entire duration of a conversation between two users. The circuit-switched technology is a highly reliable way of ensuring quality of service (QoS) for voice calls. However, this technique is not the most efficient as it puts certain limitations on the ability of the network to accommodate simultaneous voice calls at any given time. SMS, a store and forward service, uses CS.

The packet-switched (PS) technique provides much higher levels of efficiency as compared to the circuit-switched technique. It sends packets of data bursts at different time intervals while sharing the available capacity among multiple users. These packets have a header with the destination information of each packet and a payload which contains the actual data or information that is being transmitted. These headers are used by the switching nodes to determine the source and destination of the packets so that the data packets can be directed to the desired subscribers (devices) using the best possible route.

In LTE RAT, CS service means transmission on SGs (signaling gateways) so SMSs are routed over SGs interfaces or over IMS. For multi-mode devices, CS service also means CSFB of speech calls from LTE to legacy RATs when VoLTE services are not supported or not accessible.

EPS (Evolved Packet System) is the evolution of PS for 4G.

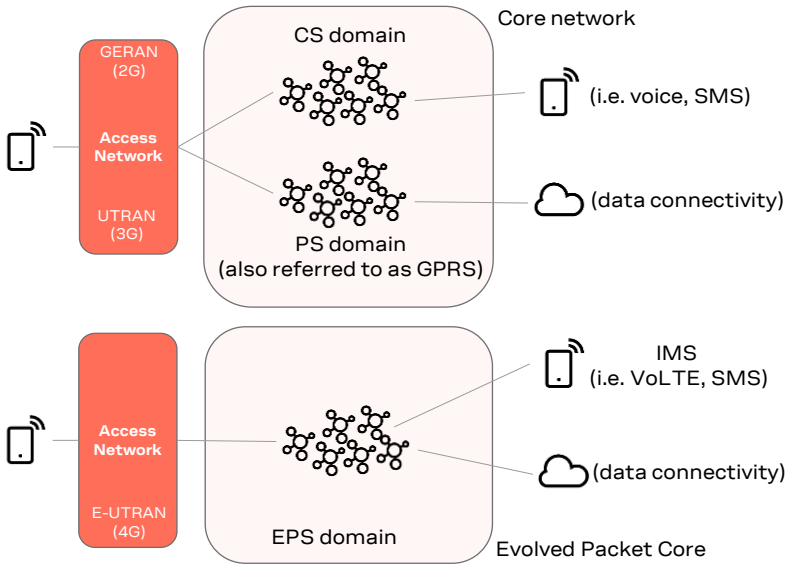

Figure 4: CS vs PS block diagram

C Glossary

Abbreviation	Definition
CHAP	Challenge handshake authentication protocol
CSFB	Circuit Switched Fallback
DCE	Data Circuit-terminating Equipment / Data Communication Equipment
DL	Down Link (Reception)
DRX	Discontinuous Reception
DTE	Data Terminal Equipment
eDRX	Extended DRX
EFS	Embedded File System
FW	Firmware
HW	Hardware
LwM2M	Lightweight M2M
MNO	Mobile Network Operator
MO	Mobile Originated
MT	Mobile Terminated
NVM	Non-Volatile Memory
NW	Network
OPLMN	Operator Public Land Mobile Network
PAP	Password authentication protocol
PLMN	Public Land Mobile Network
PPP	Point-to-Point Protocol
RAT	Radio access technology
RPLMN	Registered Public Land Mobile Network
SW	Software
TAU	Tracking Area Update
UE	User Equipment
URC	Unsolicited Result Code

Related documentation

[1] u-blox LARA-R6 / LARA-L6 series AT commands manual, UBX-21046719
[2] u-blox LARA-R6 series data sheet, UBX-21004391
[3] u-blox LARA-L6 series data sheet, UBX-21047783
[4] u-blox LARA-R6 / LARA-L6 series system integration manual, UBX-21010011
[5] u-blox LARA-R6 / LARA-L6 series Linux integration application note, UBX-22026570
[6] u-blox LARA-R6 / LARA-L6 FW update application note, UBX-22008011
[7] u-blox LARA-R6 Internet applications development guide application note, UBX-22001854
[8] u-blox Positioning implementation application note, UBXDOC-686885345-1826
[9] u-blox Mux implementation in cellular modules application note, UBX-13001887
[10] u-blox LARA-R6 / LARA-L6 LwM2M objects and commands, UBX-22008379
[11] u-blox LARA-R6 series audio application note, UBX-22001999
[12] u-blox EVK-R6 / EVK-L6 user guide, UBX-21035387
[13] u-blox LARA-R6-L6 production and prototype validation guidelines application note. UBX-22013369. Contact tech support for this document.
[14] 3GPP TS 24.008 - Mobile radio interface layer 3 specification
[15] 3GPP TS 27.010 V3.4.0 - Terminal Equipment to User Equipment (TE-UE) multiplexer protocol (Release 1999)
[16] 3GPP TS 31.102 - Characteristics of Universal Subscriber Identity Module (USIM) application (Release 14)
[17] ETSI TS 102.221 - UICC-Terminal interface; Physical and logical characteristics (Release 14)
[18] GSMA TS.34 - IoT Device Connection Efficiency Guidelines (Version 4)
[19] u-blox SARA-R422 / LEXI R422 application development guide application note, UBX-20050829
[20] u-blox module USB driver v2.0.0.0 for Windows

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Revision history

Revision	Date	Name	Comments
R01	20-May-2022	mdem / psca	Initial release
R02	13-Dec-2022	dtro / mrod / mreb / acom	Updated section SIM, Global profile, and Verizon profile information. Added information of DTR handling for PPP.
R03	31-Mar-2023	mreb / fabe / dtro	Extended document applicability to LARA-L6. Updated Backup & Restore feature.
R04	27-Feb-2024	dtro	Added RmNet support for LARA-R6 "01B" product version.

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