



SARA-R41 series

Application development guide

Application note



Abstract

This document provides detailed technology architecture and examples of how to use AT commands with u-blox SARA-R4 series modules.

Document information

Title	SARA-R41 series	
Subtitle	Application development guide	
Document type	Application note	
Document number	UBX-18019856	
Revision and date	R13	08-Jul-2022
Disclosure restriction	C1-Public	

Product status	Corresponding content status	
Functional sample	Draft	For functional testing. Revised and supplementary data will be published later.
In development / Prototype	Objective specification	Target values. Revised and supplementary data will be published later.
Engineering sample	Advance information	Data based on early testing. Revised and supplementary data will be published later.
Initial production	Early production information	Data from product verification. Revised and supplementary data may be published later.
Mass production / End of life	Production information	Document contains the final product specification.

This document applies to the following products:

Product name	
SARA-R410M	Except "01" product version
SARA-R412M	

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1 Introduction

This document provides guidance for developing applications with LTE Cat M1 and NB-IoT technologies. It includes examples of AT commands used to interface with the u-blox SARA-R4 series modules for network connectivity.

[Table 1](#) shows a summary of the documentation available for SARA-R4 series modules.

	Document name	Notes
Application integration	Application development guide app note	This document. Start here!
	FW update app note [4]	FW update procedures (uFOTA, FOAT, FOTA, +UFWINSTALL, EasyFlash).
	IoT Security-as-a-Service overview [10]	IoT-as-a-Service features (local encryption, E2E encryption, E2E symmetric KMS, Chip-to-Chip, Zero Touch Provisioning).
	GNSS implementation app note [5]	GNSS interface and aiding clients. Techniques for hybrid positioning and timing indication.
	Mux implementation app note [6]	Usage of multiplexer with cellular modules.
	LwM2M objects and commands [7]	LwM2M objects and relevant AT commands
	EVK-R4 user guide [8]	Starting guide for the SARA-R4 evaluation kit.
Reference documentation	Data sheet [1]	Use these documents as hardware integration and AT commands API reference.
	System integration manual [3]	
	AT commands manual [2]	
Product release documents	Sample Delivery Note / Information Note	Delivered with every FW release.

Table 1: SARA-R4 series documentation overview

See the SARA-R4 series AT commands manual [\[2\]](#) for detailed AT command descriptions.

The following symbols are used to highlight important information within this document:

-  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 LPWAN technology overview

SARA-R4 series modules support both LTE Cat M1 and NB-IoT LPWAN technologies. SARA-R412M modules also include 2G RAT for those areas which do not have LPWAN deployed, but support 2G RAT.

Key applications using LPWAN include:

- Automotive & transportation
- Smart metering
- Smart cities
- Smart buildings
- Connected health
- Agricultural and environmental

2.1 LTE Cat M1

LTE Cat M1 is a low-power wide-area (LPWA) air interface that allows the connection to IoT and M2M devices with medium data rate requirements. It enables longer battery lifecycles and extended in-building range, as compared to standard cellular technologies such as 2G, 3G, or LTE Cat 1.

LTE Cat M1 is part of the same 3GPP Release 13 standard that also defines Narrowband IoT (NB-IoT or LTE Cat NB1) - both are LPWA technologies in the licensed spectrum. With uplink speeds of 375 kb/s and downlink speeds of 300 kb/s in half duplex mode, LTE Cat M1 specifically supports IoT applications with low to medium data rate needs. At these speeds, LTE Cat M1 can deliver remote firmware updates over-the-air (FOTA) within reasonable timeframes, making it well-suited for critical applications running on devices that may be deployed in the field for extended periods of time.

Battery life of up to 10 years on a single charge in some use cases also contributes to lower maintenance costs for deployed devices, even in locations where end devices may not be connected directly to the power grid.

2.2 NB-IoT

Narrowband IoT (NB-IoT), also known as LTE Cat NB1, is a Low Power Wide Area (LPWA) technology that works virtually anywhere. It simply and efficiently connects devices on already established mobile networks, and securely and reliably handles small amounts of infrequent two-way data. And the best is, it provides:

- Very low power consumption
- Excellent extended range in buildings and underground
- Easy deployment into existing cellular network architecture
- Network security & reliability
- Lower component cost

NB-IoT will connect many more devices to the Internet of Things and make many new applications a reality. It is optimized for applications that need to communicate small amounts of data over long periods of time. Since it operates in licensed spectrum, it is secure and reliable, providing guaranteed quality of service.

3 Application design and development

When designing a host application interfacing with a u-blox cellular module, consider the following points, as depicted in [Figure 1](#):

- 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.

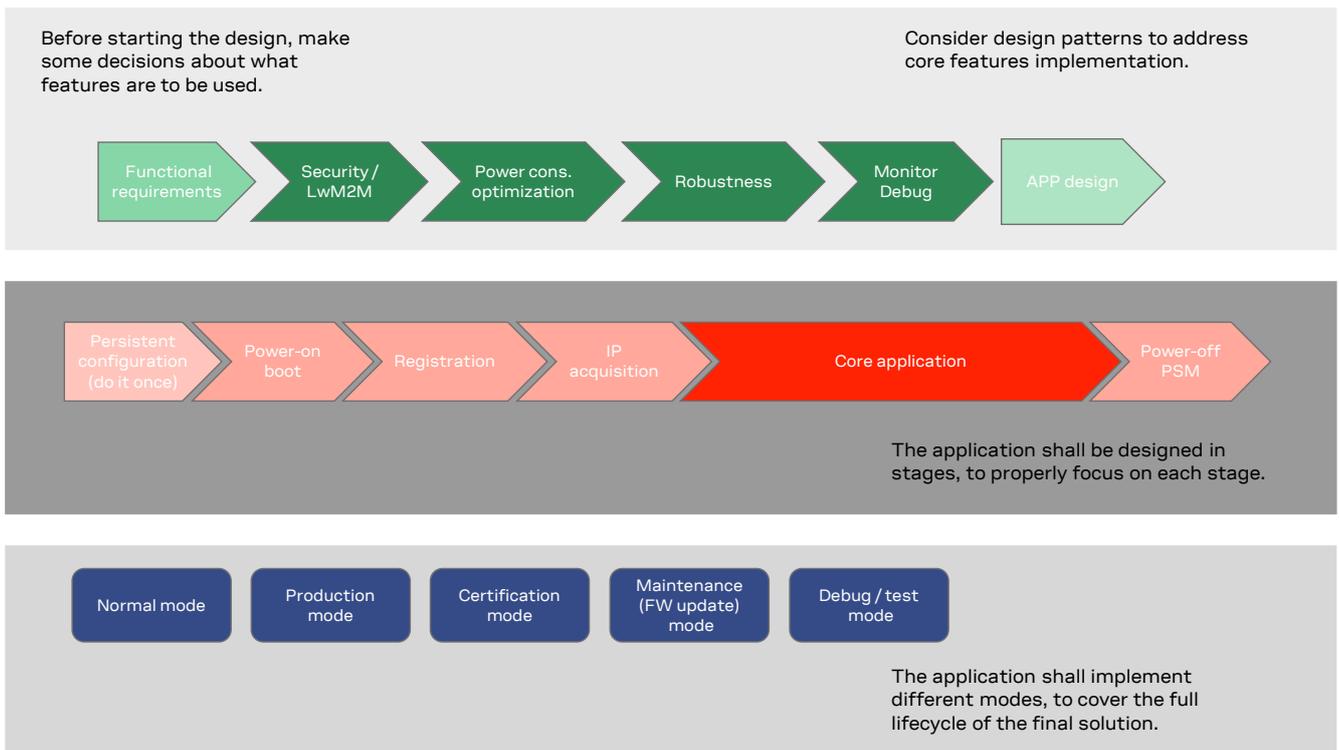


Figure 1: Application design

3.1 Initial design decisions

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 the design stage because later changes could cause much effort to adapt and validate the application.

These decisions concern:

- Usage of an LwM2M client
- Usage of security suite (if available on product type) 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 also enables automatic periodic FOTA updates when they are available, on both MNO and u-blox servers. Based on the target power consumption profile, the customer application can periodically enable the client to control features, such as the periodic LwM2M registrations with the

server or can implement alternative or additional methods to implement FW updates when triggered, for example by prolonged out of service conditions or by specific events.

Similar considerations hold for the security client.

Power saving features (+UPSV, PSM, eDRX) shall be configured based on the target power consumption profile. See section [6.1.1](#) and [18](#) for more details.

The MNO profile (section [7](#)) 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.

3.2 Application stages

3.2.1 Persistent configurations

Some module settings via AT commands are persistent and are stored in the module Non-Volatile Memory (NVM). Among them are: MNO profile, APN for Internet connectivity, active LTE bands.

The host application should implement a persistent configuration setting phase, performed once and later if needed, where all AT commands related to the required settings are issued.

 See the SARA-R4 FW update application note [\[4\]](#) for persistence of settings after a FW update. If settings are not retained, they shall be reapplied as per section [3.2.2](#).

3.2.2 Power on/boot/PSM exit

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

Not all module configurations are persistent. Therefore, after each module boot the application should again set these volatile configurations (e.g., +CMEE: 2, +CEREG, URC enabling of other commands).

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. One solution, for example, is to enable the greeting message (by means of the +CSGT AT command if available on product type); alternatively, the host application can wait for response to “AT” command.

 When using PSM, at exit from low power mode the volatile settings as well as the current communication port mode (MUX, dialup) shall be restored too.

3.2.3 Network registration

For details about the network registration stage, see section [8](#). This section covers the process for the host to understand how to optimally configure itself, what it can monitor in the process, and how to budget adequate time for networks scans.

3.2.4 IP acquisition

Once the module is registered, for LTE Cat. M1 and NB-IoT it then automatically attempts to establish PDN connectivity and active PDP context with the network. Once PDP context is on a SIM account that is subscribed to a data plan, IP is then available. For 2G connectivity on SARA-R412M, after registration the PDP context must be manually activated by the host with the +CGACT AT command.

3.2.5 Core application

For some details and guidelines on this topic, see the various data service features in this guide and SARA-R4 series AT commands manual [2]. The application shall handle AT commands, responses, and unsolicited indications. For diagnostic purposes, the application should rely on status AT commands. For robustness purposes, the application should implement embedded watchdog procedures.

3.2.6 Power-off

When the application needs to switch off the module, be sure to follow the proper shutdown procedures as described in the SARA-R4 series system integration manual [3].

3.3 Application modes

Typically, an application is designed based on its main use cases. This is what we call “normal mode”. In addition, the designer should provide a way to configure the application for alternative contexts, which can have different requirements with respect to normal mode and can help in performing other important steps in the product lifecycle.

3.3.1 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 logic.

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. This may need host application 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 solder down chip SIM is used, then consideration should be given to having a profile that can connect to test simulators during certification. (see section 25.1).

3.3.2 Production testing

This mode is to be used during the production tests of the end device. In this scenario usually the main application is inactive, and AT commands can be used to properly configure the module and use its end user testing features (see section 21).

3.3.3 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 (e.g., for throughput testing). Specific MNO tests might require the application to be running in normal mode (e.g., remote SIM provisioning, FOTA).

If a solder down chip SIM is used, then consideration should be given to having a profile that can connect to test simulators during certification. (see section 25.1).

3.3.4 Firmware update mode

A module’s firmware update should be implemented either over the air or tethered when necessary. Each update strategy has its requirements and correct implementation, which should be followed to guarantee the success of the operation. See the SARA-R4 FW update application note [4] for more details.

4 Power-on/off sequence

See the SARA-R4 series system integration manual [3] which contains important information about how to power on and off the module.

4.1 Power-on

When the SARA-R4 series modules are in the not-powered mode (i.e., the **VCC** module supply is not applied), they can be switched on by a rising edge on the **VCC** input pins to a valid voltage level, and then a low logic level needs to be set at the **PWR_ON** input pin for a valid time.

When the SARA-R4 series modules are in the power-off mode (i.e., switched off) with a valid VCC supply applied, they can be switched on by a low pulse on the **PWR_ON** pin for a valid time period.

When the SARA-R4 series modules are in Power Save Mode (PSM), with a valid VCC supply still applied, they can be switched on by a low pulse on the **PWR_ON** pin for a valid time period.

-  Before the SARA-R4 series module is fully ready to operate, the host application processor should not send any AT command over AT communication interfaces (USB, UART) of the module.
-  The duration of the SARA-R4 series modules' switch-on routine can vary depending on the application / network settings and the concurrent module activities.
-  The host application can use the `+CSGT` AT command to configure a known greeting text after the module boot to tell when the AT interface is operational.
-  The host application can use the `+UGPIOC` AT command to configure a GPIO pin to denote when the AT interface is operational.

4.1.1 Checking SIM status at boot

The SIM controller SW module may need some time to load the SIM image after boot. Therefore, when the device boots up and the AT interface becomes available, AT commands that are dependent on the SIM may return an error result code shortly after the module boot-up. The reason is the internal SIM controller, and its tasks may need additional time to complete initialization. This timing can vary from one SIM type / configuration to another. Example: SIM #1 from 'MNO #1' may take a two hundred milliseconds longer to load than SIM #2 from 'MNO #2'.

-  Both "Module Status Indication" enabled by `+UGPIOC` and `+CSGT` greeting text feature, the internal SIM controller may not be ready after either feature indicates the module is ready with AT command interface available.

If an error result code is returned from such a command such as `+CPIN`, then the host could poll the module with the same command until it returns a response indicating the SIM controller is initialized and ready. As an example with the `+CPIN` AT command and a SIM that is not PIN-locked, after module boot-up and when the AT interface becomes available, the host would then poll every 100 ms or longer until `+CPIN: READY` is returned.

4.2 Power-off

SARA-R4 series modules can be cleanly switched off by:

- +CPWROFF AT command
- Low pulse on the **PWR_ON** pin for a valid time period
- Module going into the PSM

An abrupt under-voltage shutdown occurs on SARA-R4 series modules when the **VCC** module supply is removed or when a low level is applied on **RESET_N** pin. If this occurs, it is not possible to perform the storing of the current parameter settings in the module's non-volatile memory or to perform the clean network detach.

-  Currently the only way to know when to remove **VCC** is to monitor **V_INT** pin and wait until it is at 0 V.
-  An abrupt removal of the **VCC** supply during SARA-R4 series modules normal operations may lead to an unrecoverable faulty state and must be avoided.
-  Forcing a low level on the **RESET_N** pin during SARA-R4 series modules normal operations may lead to an unrecoverable faulty state and must be avoided.

5 AT command response parser

This section gives some hints about how to develop an AT parser and how to handle the responses to the AT commands and the URCs (unsolicited result code).

In this document the following naming conventions are used:

- DCE (Data Communications Equipment) or MT (Mobile Terminal) is the u-blox module
- DTE (Data Terminal Equipment) or TE (Terminal Equipment) is the terminal that sends the command to the module

When entering AT commands, spaces are ignored. The DCE uses carriage-return line-feed pairs (`\r\n`, `0x0D0A`) to end lines on its output. The same termination is required on input to the DCE.

When the DCE has finished processing a command it will output a final result code (either `OK` or `ERROR`) indicating that it is ready to accept a new command. The information text responses are issued before the final code.

5.1 Unsolicited result code

An unsolicited result code (URC) is a string message (provided by the DCE) that is not a response to a previous AT command. It can be output, when enabled, at any time to inform the DTE of a specific event or status change. Examples of some URCs are as follows:

- | | |
|---|--|
| • <code>+CEREG: <stat>[,<tac>,<ci>,<Act>]</code> | Network registration |
| • <code>+CGEV: ME PDN ACT <cid>[,<reason>[,<cid_other>]]</code> | The MT has activated a primary context |
| • <code>+ULWM2MSTAT: <stat>,<percent></code> | FOTA status update |
| • <code>+UUSOCL: <socket></code> | Socket closed |

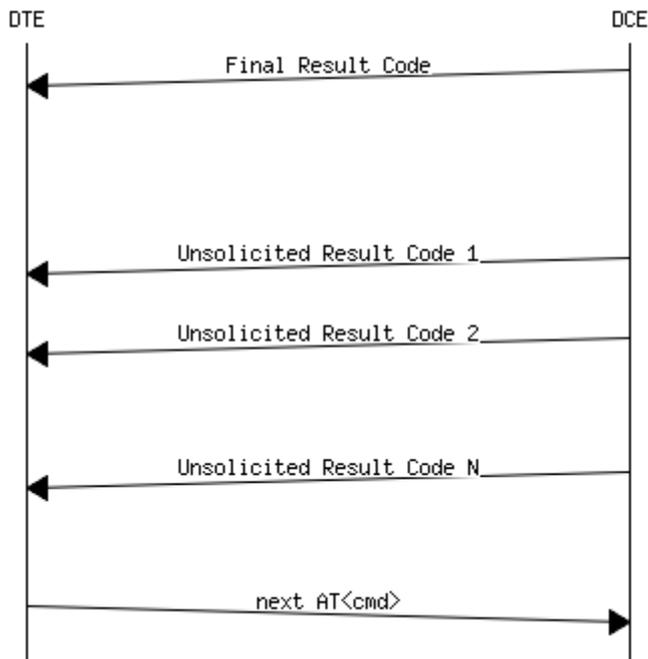


Figure 2: DTE-DCE URC flow chart

5.2 Best practices

- The DTE should flush the AT channel (i.e., check if there is data waiting to be read) before sending a new AT command.
- The DTE should handle the case of unexpected spaces or line endings.
- The DTE should handle all the URCs: it can simply ignore them (not suggested) or, better, take a proper action.
- The DTE should know what answer is expected and should wait until it is received (i.e., final result code only or information text response with the final result code).
- The final result code marks the end of an AT command and can be `OK` or `ERROR`. When the final result is an error, be sure to handle it before continuing with the next AT command.
- The information text response format is command specific. The DTE will need explicit handling for each one. It is suggested to consult the SARA-R4 series AT commands manual [\[2\]](#).
- It is suggested to not strictly parse information text responses but rather to check if they contain interesting keywords and/or parameters.
- It is very useful, for debugging an application, to log all the command lines sent to the DCE and received from it.
- Create a state machine for the AT parser (e.g., `idle`, `waiting_response`, `data_mode`).
- The DTE shall wait some time (the recommended value is at least 20 ms) after the reception of an AT command final response or URC before issuing a new AT command to give the module the opportunity to transmit the buffered URCs. Otherwise, the collision of the URCs with the subsequent AT command is possible.

6 Port selection

6.1 AT interface

SARA-R4 series modules automatically detect which interface is being used for AT commands. If the USB interface is present by means of the **VUSB_DET** pin, then the USB interface is used for AT commands. Otherwise, the UART interface is used for AT commands.

The module requires about 4 to 5 seconds to boot before the AT interface is available to the application processor.

The GPIO pins can be configured for “Module operation status indication”, which is an indicator of when the module has fully booted up and ready for AT commands. Issue the `+UGPIOC` AT command to configure which GPIO pin is used for this indication. See the SARA-R4 series system integration manual [3] for further details.

 Add USB test points to PCB design. This is critical to allow for other logging tools beyond m-center, and to provide the ability to flash the module via EasyFlash.

6.1.1 Interface power saving

The module can go into a low power idle mode where the AT interface is turned off after 6 s of inactivity. This can reduce the power consumption of the module between gaps in AT communication.

When in low power idle mode, the module switches to the active mode upon data reception over the UART serial interface. The first character received in low power idle mode wakes up the system. This extra character is not recognized as valid communication character, and the recognition of the subsequent characters is guaranteed only after the complete system wake-up.

 It is recommended to use a minimal of 40 ms for waking up the AT interface when in low power idle mode with the power saving enabled.

When in low power idle mode, the module still switches to the active mode when it is required to listen to the paging channel of the current base station. In between the module switches back to low power idle mode.

To enable and disable the power saving feature the host application should use the `+UPSV` AT command. See the SARA-R4 series system integration manual [3] for further information about power saving using the `+UPSV` AT command.

6.2 Multiplexer implementation (UART)

SARA-R4 series modules support the multiplexer as defined in the 3GPP TS 27.010 [15]. This allows the control channel to operate on one channel and AT commands to operate on another channel.

For more details how to use the `+CMUX` AT command to configure the multiplexer channels, see the SARA-R4 series system integration manual [2].

6.2.1 DLCI mapping (channel support)

SARA-R4 modules support three channels (DLCI mapping):

- Channel 0: control channel, transparent to applications
- Channel 1 – 2: AT commands / data connection
- Channel 3: GNSS tunneling data is sent to the host over this channel

6.2.2 Limitations

The multiplexer implementation has the following limitations:

- **9600 b/s baud rate is not supported.**
- When an AT command (except ATD) is sent on the channel 1, the application must wait for a response prior to sending another AT command on any other channel and vice versa.
- For commands such as +URDFILE and +USODL, that do not return “OK” right away, the application must wait for the command to finish execution and return the “OK” final result code prior to sending another AT command on any other channel and vice versa.
- When ATD is sent on the channel 1 and displays “CONNECT” intermediate result code, the application may proceed to send another AT command on any other channel and vice versa.
- When a dial-up call is active on the channel 1, the application cannot use any AT commands that require data services on any other channel. This includes FTP, HTTP, and sockets.
- The +CMUX command cannot be used again once the multiplexer has been enabled.
- The UART baud rate cannot be changed after the multiplexer enabling, so the +IPR command should be used to set the desired baud rate prior to using the +CMUX command.
- The software flow control (Xon/Xoff) is not supported and should be disabled.
- Multiplexer power control and wake-up mechanism (as described in the 3GPP 27.010 TS [15]) are not supported.
- The multiplexer is supported only on the UART interface. Only one interface can be used at a time.
- If direct link mode +USODL is used on one channel, then AT commands functionality over any other channels will not be available.
- The RI indication for an incoming SMS through the MUX MSC message is not supported.
- When the MUX is used, the URC to indicate when an incoming SMS is received is not supported.

6.3 RING indication

SARA-R4 series modules can be configured for RING pin indication via the +UGPIOC AT command. Pin 7 is configured for RING output only.

-  When the module is in PSM, the RING indication will not be emitted.
-  The GPIO can also be configured to note when the AT interface is ready. This can be used to detect when the module has been woken up from PSM. See the +UGPIOC AT command description for further information.

7 MNO profiles

Mobile Network Operator (MNO) profiles provides with a powerful and flexible method to configure the SARA-R4 module to seamlessly work with the selected operator.

Using the MNO profiles the SARA-R4 module is dynamically configured to use the proper bands, RATs, power saving parameters, eDRX parameters and the operator-dependent protocol stack settings needed to operate on the selected network in full compliance with the operator requirements.

With the MNO profiles, 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. MNO profiles are decoupled from the module firmware and therefore can be dynamically updated (for example in case of network parameters change) – even after deployment – without the need of updating the modem firmware.

In addition, generic MNO profiles are provided to provide full module configurability to the applications.

Use the `+UMNOPROF` AT command to select a profile for the network operator.

SARA-R4 modules certified for specific operators should use the corresponding MNO profile to meet operator requirements for which it was certified. For example, if a SARA-R410M-52B is certified for the AT&T network the host application should set the `+UMNOPROF` to the corresponding AT&T profile.

-  To view the list of available MNO profiles, use the `+UMNOPROF` test command.
-  Use `AT+UMNOPROF=, 1` to enable the version text of the profile when they are listed using the above command. For more details, see the SARA-R4 series firmware update application note [\[4\]](#).
-  For use on other networks that are not listed, if it is available on the product, use the MNO profile 100 (standard European) and configure RATs and bands accordingly.

This section covers some MNO profiles that are made available on certain products. For the list of MNO profiles available on each of the product types and their settings for that product, see the SARA-R4 series AT commands manual [\[2\]](#).

7.1 Using MNO profiles

To configure the module to use an MNO profile the host must first select the profile using the ID number and then reset the module (with the `+CFUN` AT command) . When the module reboots it will configure itself to use the parameters specified by the MNO.

The factory-programmed configuration or initial default state of the module of the MNO profile depends on the SARA-R4 product version:

- SARA-R4 “02” / “52” product versions: profile 0
- SARA-R4 “63” product version: profile 28 (SoftBank)
- SARA-R4 “73” product version: profile 39 (SK Telecom)
- SARA-R4 “83” product version: profile 4 (Telstra)

-  The host application must specify an MNO profile.
-  Reboot the module with the `AT+CFUN=15` command to make the MNO profile active.

7.1.1 MNO profile 0 (undefined)

It is strongly recommended to configure the module to the applicable MNO profile, RAT, and LTE bands intended for the application device and within regulatory compliance. The module is not intended to be used in the `+UMNOPROF: 0` configuration on a real network. It is recommended to use this undefined profile during production or laboratory testing only. With this profile LwM2M is disabled.

From a regulatory perspective, MNO profiles do not affect the low-level RF performance of the module. Some profiles, however, may enable features not available on a simulated network which are known to interfere with laboratory measurements. By setting to the `+UMNOPROF: 0` configuration, unexpected behavior during RF testing is reduced.

7.1.2 MNO profile 1 (SIM ICCID select)

 MNO profile 1 uses a pre-loaded issuer identifier number (IIN) database to select the MNO profile. If the SIM IIN is not in the database, it will not be recognized.

The MNO profile 1 will read the SIM ICCID number and use the IIN information to select the MNO profile. If the SIM ICCID is not recognized as belonging to an existing MNO profile, then the previous setting will be used.

 The previous setting may also include MNO profile 0. Use `AT+UMNOPROF=1` to enable SIM ICCID select mode.

See Appendix C for IIN values stored in lookup database.

The `AT+UMNOPROF=1` behavior differs between products. For more details, see the three tables below.

SARA-R410M-02B-00, SARA-R410M-52B-00, SARA-R412M-02B-00, SARA-R412M-02B-01, SARA-R412M-02B-02

Command	Response	Description
<code>AT+UMNOPROF=1</code>	OK	Select the SIM ICCID select mode.
		Insert or switch to different SIM.
<code>AT+CFUN=15</code>	OK	Reset the device.
		The device will reboot twice.
<code>AT+UMNOPROF?</code>	+UMNOPROF: 2 OK	Upon the module boot-up check the carrier profile that has been set.

SARA-R410M-02B-01, SARA-R410M-52B-01, SARA-R410M-02B-02, SARA-R410M-52B-02, SARA-R410M-02B-03, SARA-R412M-02B-03, SARA-R410M-02B-04, SARA-R412M-02B-04

Command	Response	Description
<code>AT+UMNOPROF=1</code>	OK	Select the SIM ICCID select mode.
		Insert or switch to different SIM.
<code>AT+CFUN=15</code>	OK	Reset the device.
<code>AT+UMNOPROF?</code>	+UMNOPROF: 0 OK	Upon the module boot-up ICCID select mode is exercised.
<code>AT+CFUN=15</code>	OK	Reset the device to activate the auto selected profile.
<code>AT+UMNOPROF?</code>	+UMNOPROF: 3 OK	Upon the module boot-up check the carrier profile that has been set.

SARA-R4 “63” / “73” / “83” product versions

Command	Response	Description
AT+UMNOPROF=1	OK	Select SIM ICCID select mode.
		Insert or switch to different SIM.
AT+CFUN=15	OK	Reset the device.
AT+UMNOPROF?	+UMNOPROF: 1, 0 OK	Upon the module boot-up ICCID select mode is exercised.
AT+CFUN=15	OK	Reset the device to activate the auto selected profile.
AT+UMNOPROF?	+UMNOPROF: 1, 4 OK	Upon boot-up check the carrier profile that has been set.

7.1.3 MNO profile 100 (Standard Europe)

The MNO profile 100 should be used as the basis for all other MNOs in Europe outside of Vodafone and Deutsche Telekom. However, there may be changes that need to be applied to the module for proper operation with any given MNO such as attach type, RAT preference, band selection, etc. Please consult with the preferred network provider.

If the device is attaching to a network operator (even outside of Europe) that is not listed in the MNO profile list, MNO profile 100 should be used as a generic and configurable profile

Also, it is recommended to use this profile for mobile virtual network operator (MVNO) and/or roaming SIMs. For example, in the USA region, for a roaming SIM that is not branded and issued directly from AT&T use this profile instead of MNO profile named specifically “AT&T” such as MNO 2 or 198.

7.1.4 MNO profile 101 (Standard Europe No-ePCO)

This profile is similar to MNO profile 100. The only difference is an extended Protocol Configuration options (ePCO) container is not used in NAS (Network Access Stratum) messaging when attaching to an LTE network. It has been found that some NB1 mobile operators do not support ePCO container. Therefore, if ePCO is used in the attach for such a network, this will result in lack of DNS capabilities. For NB1 networks that are known to not support ePCO, this profile is recommended.

The host may need to reconfigure this MNO profile for the intended network with parameters such as attach type, RAT preference, band selection, etc.

The Standard Europe No-ePCO profile is not supported by SARA-R4 “52” / “63” / “73” product versions.

7.1.5 MNO profile 102 (Standard JP)

On SARA-R410M-63B-01, this MNO 102 Standard JP profile is intended for MVNO and/or roaming SIMs for Japanese networks. The concept is similar to the standard Europe profile, but specific to the Japan market on the products that feature this profile. Use this profile instead of using dedicated carrier MNO profiles intended for matching carrier SIMs, such as for SoftBank or DoCoMo.

The host may need to reconfigure this MNO profile for the intended network with parameters such as attach type, RAT preference, band selection, etc.

7.1.6 MNO profile 3 (Verizon)

MNO profile 3 is configured for Verizon Wireless. This will clear the attach EPS bearer APN string and automatically define all the Verizon APNs in +CGDCONT context identifier list. For more details, see section [10.1](#).

7.1.7 MNO profile 20 (DoCoMo)

On SARA-R410M-63B-01, on Docomo’s network with this profile, the LwM2M client will connect to Docomo’s LwM2M server for DM (Device management) services. This includes FOTA FW update capability, amongst others that DoCoMo may exercise between OMA object IDs from 0 to 7.

On SARA-R410M-63B-01 the default LwM2M binding mode on the module’s client is different than the LwM2M server and this mismatch prevents the client to register with the server. DoCoMo requires LwM2M DM to be enabled, therefore the host application needs to modify the DoCoMo DM server binding mode with the following procedure outlined below.

Changing binding mode with Docomo LwM2M DM server when <MNO>=20 profile used

Command	Response	Description
AT+ULWM2MSTAT=1	OK	Enable the LwM2M URCs.
AT+CFUN=15	OK	Perform a reset. This is to catch any URCs from LwM2M client from boot-up.
	+ULWM2MSTAT: 1, 123, 2	Wait for notification of LwM2M bootstrap completed.
AT+ULWM2MWRITE="{\"bn\": \"1/0/\", \"e\": [{\"n\": \"7\", \"sv\": \"UQ\"}]}"	OK	Modify the DoCoMo server instance by setting binding mode to "UQ".
AT+ULWM2MSTAT=0	OK	As an option, the host can perform this step to disable LwM2M URCs

Per MNO requirements, it is required by DoCoMo when using SARA-R410M-63B-01 with MNO 20 to change the binding mode as described in the above to support DoCoMo DM server.

LwM2M is disabled by default for the DoCoMo profile. If a user should subscribe to DoCoMo LwM2M services, then DoCoMo will permit the LwM2M client to be turned on via AT+ULWM2M=4. If the LwM2M service subscription is later terminated, cancelled, or discontinued, then the host must disable the LwM2M client with AT+ULWM2M=3 per DoCoMo’s requirement.

7.1.8 Configuration for T-Mobile US network

This section is only applicable to modules that do not support the T-Mobile US MNO profile (+UMNOPROF: 5) but are certified for T-Mobile US network operations.

For end devices using a T-Mobile US SIM and that will certify with the operator, the configuration procedure should be performed:

- Set MNO profile to Sprint (+UMNOPROF: 8).
- Configure the active bands to only band 2 and 12.

Configuring profile for T-Mobile US

Command	Response	Description
AT+UMNOPROF=?	0: SW default 1: SIM ICCID select 2: ATT 3: Verizon 4: Telstra 8: Sprint 19: Vodafone 21: TELUS	Optionally read allowed MNO profiles

Command	Response	Description
	31: DT 33: VIVO 43: ROGERS 44: Claro Brasil 45: TIM Brasil 46: Orange France 100: Standard Europe 101: Standard Europe No-ePCO 198: AT&T Profile 2-4-12 206: FN ATT OK	
AT+UMNOPROF=8	OK	Select Sprint MNO profile.
AT+CFUN=15	OK	Reboot the module.
AT+UMNOPROF?	+UMNOPROF: 8 OK	Check the active MNO profile by the +UMNOPROF read command..
AT+CFUN=0	OK	
AT+UBANDMASK?	+UBANDMASK: 0,16779274,1,16779274 OK	Read default band mask
AT+UBANDMASK=0,2050		Configure the LTE-M band mask to enable only band 2 and 12
AT+CFUN=15		Reboot the module.
AT+UBANDMASK?	+UBANDMASK: 0,2050,1,16779274 OK	Check band mask is set correctly

7.1.9 Modifiable parameters

MNO profiles configure the module with a set of parameters. Depending on the MNO profile, some of these parameters can be overridden by using AT commands. Below is a list of AT commands which can be used to set the module configuration after it has turned on.

- +UBANDMASK Band mask
- +URAT RAT priority list
- +CPSMS PSM timer values (T3324, T3412)
- +CEDRXS eDRX configuration
- +CGDCONT APN and PDP context
- +USCVDOMAIN Attach type: EPS only or combined attach

If the host changes any of these parameters, they will be retained after a module reset.

To see what parameter can be reconfigured for a given MNO profile, see SARA-R4 series AT commands manual [\[2\]](#).

7.1.10 Resetting MNO profile parameters

To reset back to the MNO profile parameter values the host will need to move to another MNO profile and then back again. Sending the same AT+UMNOPROF AT command will also not reset the changed parameters. Each time the host must reboot the module.

8 Registration with LPWAN network

At the 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 and other attach parameters.

Once the module has found a cell it can camp on, it will start the registration process. If the SIM card has a valid account, it will start the provisioning process automatically. The `+CPIN` AT command may need to be entered for the device to start the provisioning process.

- Use `+CNUM` and `+CGDCONT` AT read commands to view the MDN number and APN assigned after the module has registered on the network. (Not all network operators assign an MDN.)
- Use the `+COPS` AT read command to view the network information, and the `+CESQ` AT command to check the signal conditions.
- If the SIM card is locked with a PIN, then the LwM2M client may not be properly configured, since it will not be able to retrieve SIM information. This is most relevant in Verizon MNO profile (`+UMNOPROF: 3`) where the SIM information is used to build the DUT endpoint name. It is then recommended to insert the SIM PIN, if enabled, within 10 s of the module boot.
- Configure the module to the desired MNO profile for it to function properly on the network it is intended to be used on. Set the MNO profile on the very first use, or after flashing new firmware.
- Applications shall select a proper MNO profile and not leave the factory-programmed undefined profile.

8.1.1 Radio Access Technology (RAT)

Use the `+URAT` AT command to select the order of preference of networks the module should try.

Each MNO profile has a defined RAT search priority.

The module will search all the bands configured in the `+UBANDMASK` list on each RAT before moving on to the next RAT in the priority list. This means if only 2G services are available and the module is configured for all bands in LTE Cat M1 and NB-IoT, it may take many minutes to finally select a 2G network.

8.1.2 Band configuration

SARA-R4 series modules can scan 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.

Use the `+UBANDMASK` AT command to specify these bands as an 8 byte bitmask. Each band is enabled by summing the band values together, where each band value is represented by $2^{(\text{band}-1)}$. For example:

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	SUM		
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			
Enable B20 only	0	0	0	0	0	0	0	0	2^{19}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2^{19}	524288
Enable 2,4,5,12 only	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2^{11}	0	0	0	0	0	0	0	2^4	2^3	0	2^1	0	$2^{11}+2^4+2^3+2^1$	2074
Enable 4 & 13 only	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2^{12}	0	0	0	0	0	0	0	0	2^3	0	0	0	$2^{12}+2^3$	4104	

Use these values for +UBANDMASK

- Each MNO profile will define a set of bands to scan on.
- LTE Cat M1 and NB1 both have individual band masks, which need to be configured separately. `AT+UBANDMASK=0,<band mask>` for LTE Cat M1, `AT+UBANDMASK=1,<band mask>` for NB1.

8.1.3 Network scan and search

SARA-R4 series modules will scan each band configured for each RAT selected. By reducing the number of bands and selecting only one RAT, the module may attach to a network quicker than if all bands are configured.

SARA-R4 series modules perform a network search and selection according to 3GPP TS 23.122. The module tracks the PLMN / band information of scanned cells in addition to the PCI (Physical Cell ID) of the cell it attaches to in a local acquisition table, which it looks up to when there is a loss of signal. Upon start-up, the module will first look at this acquisition table for a previously camped cell to try and attach to it. If the acquisition list is empty or if none of the cells in the table are available to be seen, the module will restart scanning the RATs (in order of priority) and bands (in an increasing numerical order) that have been configured in the MNO profile.

The +URAT and +UBANDMASK [if available to reconfigure in the active MNO profile] AT commands contain the RAT preference and LTE bands, respectively. In general, the band scan process for LTE Cat. M1 (1.4 MHz at a time) bands takes just a few seconds in comparison to NB1 which can take about 2 minutes per band (100 kHz at a time and this is per design).

Because NB-IoT allows for cells to be found with much higher dynamic range, the scan time in NB-IoT is much longer than LTE Cat M1. If the application has configured NB-IoT as well as a LTE Cat M1, but there are no NB-IoT networks the module may take a couple minutes per band to complete the NB-IoT scanning before re-trying the LTE Cat M1 RAT scan.

8.1.4 +UMACQOSTMR timer configuration

 The +UMACQOSTMR AT command is supported by SARA-R4 “02” product versions except for SARA-R410M-02B-00, SARA-R410M-02B-01, SARA-R410M-02B-02, SARA-R412M-02B-00, and SARA-R412M-02B-01.

The +UMACQOSTMR AT command allows configuration of a MAC layer timer that acts as an optional and additional mechanism that can be enabled to ensure LTE network local RRC release and return to idle after prolonged RX and TX inactivity of the radio channel. It is referred to being an “additional back-up mechanism”, since the RRC procedure would normally handle the local RRC release. However, if there is a rare instance that it does not release timely with a network, this mechanism provides added reliability. An optimal and timely local RRC release is important to ensure the proper handling of any potential inbound network pages.

Timer recommendations:

- If a timer is not enabled by default in MNO profile, enable the timer for LTE-M via +UMACQOSTMR AT command.
- Use an optimal timer value of 90 s.

For NB-IoT there is no recommendation to have it enabled.

Check in the appendix of the SARA-R4 series AT commands manual [2] for details on the default +UMACQOSTMR settings in the Mobile Network Operator profiles section.

Example sequence to configure the +UMACQOSTMR AT command setting:

Command	Response	Description
AT+UMACQOSTMR?	+UMACQOSTMR: 35,-1 OK	Read +UMACQOSTMR timer configuration.
AT+UMACQOSTMR=90	OK	Set timer value to 90 s for LTE Cat M1.
AT+CFUN=15	OK	Reset the device to make persistent setting effective.

Command	Response	Description
AT+UMACQOSTMR?	+UMACQOSTMR: 90,0 OK	Read UMACQOSTMR timer configuration to confirm change.

When using network simulators, to perform certain types of measurements there may be a need to stay in local RRC connected state. See section 21.2 for details for guidance to disable the timer in such situations.

8.1.5 First time registration setup

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 applied after +URAT or +UBANDMASK, it will override any past configuration the host application has made.

 The host application should always set the MNO profile.

 For standard European operation when the MNO is not listed, use MNO profile 100.

After setting the MNO profile the application may modify the Radio Access Technology priority and band mask.

Possible reason for setting +URAT may include:

- Radio Access Technology is not deployed by the network carrier yet in the area device is intended to run on. Therefore, only enabling the desired RAT will reduce the scan time when the device is searching for the network.

Possible reason for setting +UBANDMASK may include:

- Band(s) is not deployed by the carrier yet in the area device is intended to run.
- The device is an area where it is interested in running on specific bands only.
- Reducing the number of bands will reduce the scan time when the device is searching for the network.

Below is an example of going through the above steps in configuring the SARA-R4 module:

Step #1: Set the profile to standard Europe

Command	Response	Description
AT+UMNOPROF=100	OK	Set the carrier profile to standard Europe.
AT+CFUN=15	OK	Reset the device to make setting effective.
AT+UMNOPROF?	+UMNOPROF: 100 OK	Upon boot-up check that the carrier profile is set correctly.

Step #2: Set the +URAT to LTE Cat M1 only

Command	Response	Description
AT+COPS=2	OK	Deregister from the network before setting RAT.  It is possible to issue AT+CFUN=0 or AT+CFUN=4 instead of the AT+COPS=2 command.
AT+URAT=7	OK	Set the RAT to LTE Cat M1 only.
AT+CFUN=15	OK	Reset the device to make setting effective.
AT+URAT?	+URAT: 7 OK	Check that RAT is set to LTE Cat M1 only, by the +UART read command .

Step #3: Set +UBANDMASK

Command	Response	Description
AT+UBANDMASK=0,2	OK	Set LTE Cat M1 band mask to band 2 only.
AT+CFUN=15	OK	Reset the device to make setting effective.
AT+UBANDMASK?	+UBANDMASK: 0,2,1,2074 OK	Upon reboot check the LTE-M band mask is correctly set to band 2 only.

The above two steps can be combined as such:

Command	Response	Description
AT+COPS=2	OK	Deregister with the network. It is possible to issue AT+CFUN=0 or AT+CFUN=4 instead of the AT+COPS=2 command.
AT+UMNOPROF=100	OK	Set the carrier profile to standard Europe.
AT+CFUN=15	OK	Reset the device to make the setting effective.
AT+URAT=7	OK	Set the RAT to LTE Cat M1 only.
AT+UBANDMASK=0,2	OK	Set LTE-M band mask to band 2 only.
AT+CFUN=15	OK	Reset the device to make the setting effective.
AT+UMNOPROF?	+UMNOPROF: 100 OK	Upon boot-up check that the carrier profile is set correctly.
AT+URAT?	+URAT: 7 OK	Check the +URAT status that RAT is set to LTE Cat M1 only.
AT+UBANDMASK?	+UBANDMASK: 0,2,1,2074 OK	Upon reboot check the LTE-M band mask is correctly set to band 2 only.

For more details on the AT commands used in the example, see SARA-R4 series AT commands manual [\[2\]](#).

8.1.6 Automatic and manual network registration

There are two modes for PLMN selection.

Automatic:

The AT+COPS=0 command performs an auto scan on the capable RATs of the module and search PLMNs on the module. The module will choose the best cell and PLMN that allows the subscriber (SIM card) to get on to which can take a while at times. The module will initially try looking for a HPPLMN (High priority) and if not found, the module will look for a roaming PLMN cell as a lower preference. When the auto selection is set, the module will time and again get into a scanning mode and it will keep trying to find a HPPLMN. The module will try all possible operator networks if the band being used by them has been configured on the module.

The module always prefers to be in non-roaming (with auto cops) cell. When the +URAT AT command is configured to 7, 8, 9 (on SARA-R412M) assuming operators are allowing the subscriber to Roam and if the AT+COPS=0 command is issued, the module will try looking for HPPLMN in LTE Cat. M1 followed by NB1 and then try 2G RAT. The module could end up camping on 2G (even if it is roaming) as the network allows it to camp.

If the module lands on a roaming cell, the background PLMN scans can take the module out from the PSM and result in higher average power consumption. In addition, even if the module is in connected mode, these PLMN scans will pre-emptively abort the connection and force a local channel release. This will occur per 3GPP requirements of 2 minutes after the first registration in roaming on a VPLMN at power on if the SIM card lists a higher priority PLMN with the same MCC of the current VPLMN in the Operator or User Preferred PLMN list file. Successive PLMN scan will be periodically triggered based on the values of the HPPLMN (High Priority) timer in the SIM file. Refer to the section [8.6.1](#).

The AT+COPS=2/AT+COPS=0 registration cycle in roaming might trigger the full PLMN scan, while the AT+CFUN=0/AT+CFUN=1 cycle will select the last registered PLMN without additional scans.

Manual:

The AT+COPS=1,2,"PLMN",<Act> command will do a specific manual PLMN search, the module will try to attach to a cell and even if it is roaming, it will still get on to it if the PLMN matches. With the manual AT+COPS=1, the module will reduce the scanning process as well. For e.g., if the user wants to attach to a certain carrier like AT&T on LTE Cat. M1, a AT+COPS=1,2,"310410",7 command may be issued. The manual network selection will work faster and save battery by not waiting for module do a complete scan and decide to get onto a network.

Issuing AT+UMNOPROF=100 and AT+URAT=7,8,9 (on SARA-R412M), the module will scan LTE Cat. M1 (as first preferred), NB1 (as second preferred) and 2G (as third preferred). The module will get on to LTE Cat. M1 first if available and only if there is no LTE Cat. M1 signal, the module will search for NB1 and only if there is no NB1 it will try to register on 2G RAT. If the module got on to a 2G network, it would look out for LTE Cat. M1 once again only when it loses registration on 2G RAT and switch over to LTE Cat. M1 while it is available or right away when 2G signal is lost.

2G networks in the USA have been decommissioned by some operators and may be completely shut down by remaining operators by the end of 2022.

Some networks might reject the attach if the type of attach is not allowed. The +USVCDOMAIN AT command can be set to CS+PS and the module can register to a valid network A (as supported by the SIM), but then if the module loses network A and later finds a valid network B (as supported by the SIM) that supports PS only, the module might not be able to attach to this network B. It is good to check what type of attach is preferred by a network.

8.1.7 MVNO users in the USA

In the USA, major carriers like AT&T and Verizon have a nationwide coverage for LTE Cat M1. A factor to consider when using a mobile virtual network operator (MVNO) SIM is that multiple carriers will show up with AT+COPS=? If the selected MNO profile configuration can support the type of networks/operators it can attach to.

Command	Response	Description
AT+COPS=?	+COPS: (2,"AT&T","AT&T","310410",7), (1,"313 100","313 100","313100",7), (1,"310 260","310 260","310260",0), (0,1,2,3,4), (0,1,2) OK	<ul style="list-style-type: none"> • 310410 is AT&T. • 313100 is AT&T's FirstNet. • 310260 is T-Mobile US. • 311480 is Verizon.

Reducing the number of bands to what bands are used in the USA, reduces module's scan time, and saves power. Bands available in the USA are 2,4,5,12,13.

To enable all US bands

Command	Response	Description
AT+UBANDMASK=0, 6170	OK	Setting LTE-M bands
AT+UBANDMASK=1, 6170	OK	Setting NB-IoT bands
AT+CFUN=15	OK	Reset the device to make the setting effective.

If the device has a MVNO SIM card, then the +UMNOPROF AT command can be set to <mno>=100 and the module can be reconfigured for some of the settings like +URAT, +UBANDMASK and +USVCDOMAIN appropriately. To be more efficient, for an MVNO SIM that supports multiple network

operators it is recommended that the module use the manual selection (AT+COPS=1) and pick a preferred target operator and not issue AT+COPS=0.

To get on to AT&T LTE Cat M1 only with +UMNOPROF: 100

Command	Response	Description
AT+COPS=2	OK	Deregister with the network. It is possible to issue AT+CFUN=0 or AT+CFUN=4 instead of the AT+COPS=2 command.
AT+UMNOPROF=100	OK	Set the carrier profile to standard Europe.
AT+CFUN=15	OK	Reset the device to make the setting effective.
AT+URAT=7	OK	Set the RAT to LTE Cat M1 only.
AT+UBANDMASK=0,2074	OK	Set LTE-M band mask to band 2, 4, 5, 12 only.
AT+USVCDOMAIN=2	OK	Set the Type of Attach to CS+PS
AT+CPSMS=0	OK	Disable PSM [optional]
AT+CEDRXS=0	OK	Disable eDRX [optional]
AT+USIMSTAT=4	OK	For multi IMSI MVNO SIM cards configure the +UUSIMSTAT URC to report the (U)SIM toolkit REFRESH proactive command result. For more details, see section 8.1.7.1 .
AT+UCUSATA=4	OK	For multi IMSI MVNO SIM cards, enable the +UUSIMSTAT URC by the +UCUSATA AT command. For more details, see section 8.1.7.1 .
AT+CFUN=15	OK	Reset the device to make the setting effective.
AT+UBIP=1	OK	Enable BIP indication near boot-up
AT+COPS=1,2,"310410",7	OK	Manual registration to AT&T

To get on to Verizon Cat M1 only with +UMNOPROF: 100

Command	Response	Description
AT+COPS=2	OK	Deregister with the network. It is possible to issue AT+CFUN=0 or AT+CFUN=4 instead of the AT+COPS=2 command.
AT+UMNOPROF=100	OK	Set the carrier profile to standard Europe.
AT+CFUN=15	OK	Reset the device to make the setting effective.
AT+URAT=7	OK	Set the RAT to LTE Cat M1 only.
AT+UBANDMASK=0,4096	OK	Set LTE-M band mask to band 13 only.
AT+USVCDOMAIN=2	OK	Set the Type of Attach to CS+PS
AT+CPSMS=0	OK	Disable PSM [optional]
AT+CEDRXS=0	OK	Disable eDRX [optional]
AT+USIMSTAT=4	OK	For multi IMSI MVNO SIM cards configure +UUSIMSTAT URC to report the (U)SIM toolkit REFRESH proactive command result. For more details, see section 8.1.7.1 .
AT+UCUSATA=4	OK	For multi IMSI MVNO SIM cards, use the +UCUSATA AT command to enable the +UUSIMSTAT URC. For more details, see section 8.1.7.1 .
AT+CFUN=15	OK	Reset the device to make the setting effective.
AT+UBIP=1	OK	Enable BIP indication near boot-up
AT+COPS=1,2,"311480",7	OK	Manual registration to Verizon

8.1.7.1 Multi-IMSI SIMs

The market continually offers more multi-IMSI SIMs that can roam in different regions and networks. They are typically offered by MVNO providers. These SIMs can swap IMSI depending on the local network information and eventually swapping to an IMSI designed to connect to the local network the SIM supports.

When using such a SIM it is recommend to set:

- +USIMSTAT: 4
- +UCUSATA: 4

The two configurations above will allow the +UUSIMSTAT URC to report the (U)SIM toolkit REFRESH proactive command result and so to track possible IMSI swap event.

In addition, on each boot it is advisable to enable bearer independent protocol (BIP) status indication issuing the AT+UBIP=1 command. Having it enabled will notify events for download's tag or proactive command's tag. This is useful to monitor for potential SIM applet updates, which may occur more frequently for MVNO SIMs than non-MVNO SIMs.

The example shows how to configure the URC to indicate proactive REFRESH events

Command	Response	Description
AT+USIMSTAT=4	OK	For multi IMSI SIM cards (typically MVNO SIM cards), configure the +UUSIMSTAT URC to report (U)SIM toolkit REFRESH proactive command result.
AT+UCUSATA=4	OK	For multi IMSI SIM cards (typically MVNO SIM cards), after setting +USIMSTAT, then use the +UCUSATA AT command to enable +UUSIMSTAT URC. If enabled, when there is an IMSI swap event, the SIM applet will issue a REFRESH event and the host can now be informed via the +UUSIMSTAT URC. The +CIMI AT command can be used before and/or after the +UUSIMSTAT URC to track active IMSI used.
AT+CFUN=15	OK	Reboot the module.

The example below shows how to monitor the IMSI with respect to (U)SIM toolkit REFRESH events and to enable BIP indication per each boot.

Command	Response	Description
AT+CIMI	732123203818006	Upon boot check IMSI
AT+UBIP=1	OK	Enable BIP indication near boot
	+UUSIMSTAT: 9 +UCUSATA: 4 OK	+UUSIMSTAT URC indicates (U)SIM toolkit REFRESH event.
AT+CIMI	234500029813106 OK	Check if IMSI has changed. In this example, it has.

8.2 Registration as PS connection

Use the +CEREG AT command to confirm the module is registered on the LTE network for LTE Cat M1 or NB1. Use the +CREG and +CGREG AT command for CS and GPRS network registration status.

When registering on a LTE Cat M1 or NB1 network the PDN context will be automatically created and activated; for 2G networks the host needs to manually activate the PDN context using the +CGACT AT command.

 If the uFOTA is enabled and needs to contact the uFOTA server when running on 2G, the LwM2M will automatically activate the default context.

8.2.1 PS connections at RAT change

When the module changes the RAT any PDP contexts and socket connections will be deactivated and disconnected. The host will need to re-create and re-activate socket connections. If the module had open sockets, the +UUSOCL URC will be issued when they are closed at RAT change.

LTE Cat M1 and NB1 networks, implementing the LTE standard, will automatically activate the default bearer PDP context, <cid>=1. Any other PDP context the host has configured and manually activated will have to be re-created and re-activated.

The 2G network may require the host to manual activate a PDP context as this is generally a manual procedure.

8.3 Detecting the access technology

SARA-R4 series modules can connect to different types of access technologies; LTE Cat M1, NB-IoT and GPRS in the case of SARA-R412M. Because the modules can be configured to automatically connect to any of these access technologies, there are AT commands the host application can use to detect what technology is being used.

The best AT command to use is the +COPS command. The +COPS command has a <AcT> parameter which describes the access technology the module is registered to. However, this command does not provide a URC when the module is registered.

There are other AT commands that do have a URC when the registration is made. These also describe the access technology, +CEREG for LTE (Cat M1 or NB-IoT) and +CGREG (GPRS).

Host applications should always enable the URC for +CEREG and in the case of GPRS with SARA-R412M, +CGREG. When the module registers on the network the application can read the access technology type from these URCs.

Basic operation would be:

Command	Response	Description
AT+CEREG=1	OK	Set URC for LTE
AT+CGREG=1	OK	Set URC for GPRS if using SARA-R412M
<Wait for URC>		
AT+COPS?	+COPS: 0,0,"Verizon Wireless",7 OK	Read +COPS and check <AcT> parameter for RAT

 +CREG is used to describe if the module has been registered in the Circuit Switched Domain too for Combined Attach modes.

8.4 Mobility

This section describes the procedures of the module when it moves out of range of the currently serving cell. This could mean entering another cell or moving into an area where there is no cellular coverage.

If the module loses the synchronization with the serving cell but finds another cell of the same RAT 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.

If the application has configured multiple RATs in the +URAT setting, in case the module cannot select a cell on the same RAT, it will automatically go through a re-selection process selecting a cell of

another RAT. In this case, PDP contexts will be locally deactivated and socket connections disconnected accordingly.

8.4.1 Mobility Management procedures

Mobility management procedures differ depending if the module is in idle mode or connected mode:

- Connected Mode Mobility Management describes the procedures when the module has a RRC connection established with the cellular network.
- Idle Mode Mobility Management holds when the module is synchronized on a cell without an RRC connection.

Connected Mode Mobility is handled by the eNodeB. The UE is instructed by the eNodeB to provide a measurement report so that the network can decide if and when the RRC connection has to be handed over to another cell. This is called Cell-ReDirection or Cell-Handover.

Idle Mode Mobility is handled by the UE using information transmitted in the System Information Blocks (SIB) broadcast by the cellular NW within the cell. While in idle mode the UE will make measurements of neighboring cells and based on the cell reselection criteria read in the SIBs it may choose another serving cell to synchronize with. This procedure is called Cell-ReSelection.

 Currently only SARA-R4 series “63” / “73” version modules support Connected Mode Mobility.

8.4.2 Cell to cell (same RAT), connected mode

If the module is currently camped on a cell and exchanging data in connected mode on an RRC connection, when it moves out of range a Radio Link Failure event will happen and the module will start to search for other cells.

Uplink messages will be buffered until the new cell is selected and camped on. If the TX buffer is full, new user attempts to send data will result in an error result code being returned on the AT interface.

The PDP context and any open sockets will be kept while scanning the supported band until the new cell is found.

When the new cell is found, the buffered messages will be sent.

8.4.3 Cell to no coverage, connected mode

If the module is currently camped on a cell and exchanging data in connected mode on an RRC connection, when it moves out of range a radio link failure event will happen and the module will start to scan for other cells.

Uplink messages will be buffered until the module has finished the cell search on supported bands of the same RAT; if internal sockets were used for data transfer, any UL buffered messages will be lost since they were not actually delivered, and the socket will be locally closed when the module has failed to find another cell of the same RAT to camp on. It will then pick the next RAT in the +URAT list, if any, and perform cell selection.

Once the cell selection is completed and EPS data bearer has been successfully activated, the application must take care to re-create and re-open the socket to re-establish the data transfer.

If the dial-up network was used, the no coverage transition may result transparent from the application level since the dial-up may not be released when data cannot be transferred. This depends on the dial-up functionality implementation on the host PC. In any case, the PDN contexts where the dial-up network is established will not be released upon entering out-of-coverage condition.

8.4.4 Cell to cell (same RAT), idle mode

If the module is currently camped on a cell and in idle mode, when it moves out of range it will not detect the synchronization lost immediately due to L1 optimization in paging reception.

When the application sends new data, the module will try to reconnect to the previous cell and fail. This will cause the module to scan for another cell.

The application data will be buffered while the module scans all supported bands for a new cell.

If there is another cell of the same PLMN available on the same RAT, then the module will find that cell and camp on it. The buffered application data will then be sent. PDP contexts will be kept.

8.4.5 Cell to no coverage, idle mode

If the module is currently camped on a cell in idle mode, when it moves out of range it will not know it has moved out of range of the currently camped cell. When the application sends new data, the module will try to reconnect to the previous cell and fail. This will cause the module to scan for another cell.

The application data will be buffered while the module scans supported bands for a new cell.

As there is no other cell in range the module will fail to camp, hence it will locally detach from the network and start a full scan on the next RAT in the URAT list if any. At local detach, any buffered data will be lost, PDP contexts will be locally deactivated and open sockets will be closed.

8.4.6 Inter-RAT handover and change of RAT

Inter-RAT handover is currently not supported.

However, when the module has no radio coverage on the currently selected RAT, it will re-scan for cells on the same RAT. If no cell is found, and there are other RATs in the +URAT preferred list, the module will try scanning on those technologies.

For example, on SARA-R412M the +URAT may be configured for +URAT: 7,9 which means that it should use LTE Cat M1 if possible but will try 2G network if this fails.

8.5 Registration examples

8.5.1 LTE registration (Cat M1, NB-IoT)

First the application should check to see if the module is configured for the correct connection it required. In this example it configures for NB-IoT, band 20 in the Standard Europe profile. Also, the PDP context to contain the APN is set:

Command	Response	Description
AT+UMNOPROF=100	OK	Set the standard Europe profile
AT+CFUN=15	OK	Reboot to take effect
AT+URAT=8	OK	Set the +URAT AT command to NB-IoT only
AT+CFUN=15	OK	Reboot the module to take effect
AT+UBANDMASK=1, 524288	OK	Set band to 20 only for NB-IoT
AT+CGDCONT=1, "IP", "jtm2m"	OK	Set APN to "jtm2m"
AT+USIMSTAT=4	OK	For multi IMSI MVNO SIM cards configure +UUSIMSTAT URC to report the (U)SIM toolkit REFRESH proactive command result. For more details, see section 8.1.7.1 .
AT+UCUSATA=4	OK	For multi IMSI MVNO SIM cards, use the +UCUSATA AT command to enable the +UUSIMSTAT URC. For more details, see section 8.1.7.1 .
AT+CFUN=15	OK	Reboot the module to make the changes effective.

SARA-R4 series modules will automatically try to connect when they boot. In this case it will be scanning band 20 only for NB-IoT network. The host application can poll to see when the module has registered and activated its default PDP context like this:

Command	Response	Description
AT+CEREG?	+CEREG: 0,2 OK	Module is still scanning
AT+CEREG?	+CEREG: 0,5 OK	Registered to network (roaming)
AT+CGATT?	+CGATT: 0 OK	Module is not attached to network yet
AT+CGATT?	+CGATT: 1 OK	Module is attached to network
AT+CGACT?	+CGACT: 1,0 OK	Module does not yet have an active PDP context
AT+CGACT?	+CGACT: 1,1 OK	Module now has an active PDP context
AT+CGDCONT?	+CGDCONT: 1, "IP", "j2m2m", "91.80.104.82", 0,0 OK	Module has an IP address
AT+USOCR=17	+USOCR: 0 OK	Create a UDP socket. Socket ID 0 is returned
AT+USOST=0, "195.34.89.241", 7, 2, "AB"	+USOST: 0,2 OK	Send 2 bytes to u-blox echo server
<wait for +UUSORF URC>	+UUSORF: 0, 2	Socket ID 0 has 2 bytes to read
AT+USORF=0,2	+USORF: 0, "195.34.89.241", 7, 2, "AB" OK	Read back 2 bytes from socket ID 0
AT+USOCL=0	OK	Close socket ID 0

8.5.2 GPRS registration (2G – SARA-R412M only)

First the application should check if the module is configured for the correct connection it required. This example is configured for 2G RAT with the PDP context to contain the APN:

Command	Response	Description
AT+UMNOPROF=100	OK	Set the profile. In this example MNO profile 100 is selected, since it provides access to 2G RAT ¹ .
AT+CFUN=15	OK	Reset the module to complete activate the MNO profile selection.
AT+UMNOPROF?	+UMNOPROF: 100 OK	Check the MNO profile comes up after boot. In this example it is verified correct with 100.
AT+URAT=9	OK	Set +URAT to 2G only. Only selected profiles allow URAT to be reconfigured. ¹
AT+CFUN=15	OK	Reboot the module to take effect.
AT+CGDCONT=1,"IP","jtm2m"	OK	Set APN to "jtm2m".
AT+CFUN=15	OK	Reboot the module to take effect.

The SARA-R4 series modules will automatically try to connect when they boot. In this case it will be scanning for a 2G connection. The host application can poll to see when the module has registered and activated its default PDP context like this:

Command	Response	Description
AT+CGREG?	+CREG: 0,2 OK	Module is still scanning.
AT+CGREG?	+CREG: 0,5 OK	Registered to network.
AT+CGATT?	+CGATT: 0 OK	Module is not attached to network yet.
AT+CGATT?	+CGATT: 1 OK	Module is attached to network.
AT+CGACT?	+CGACT: 1,0 OK	2G networks will not automatically activate the PDP context: it must be done this manually (in general).
AT+CGACT=1	OK	Module now has an active PDP context.
AT+CGDCONT?	+CGDCONT: 1,"IP","j2m2m","91.80.104.82",0,0 OK	Module has an IP address.
AT+USOCR=17	+USOCR: 0 OK	Create a UDP socket. Socket ID 0 is returned.
AT+USOST=0,"195.34.89.241",7,2,"AB"	+USOST: 0,2 OK	Send 2 bytes to u-blox echo server.
<wait for +UUSORF URC>	+UUSORF: 0, 2	Socket ID 0 has 2 bytes to read.
AT+USORF=0,2	+USORF: 0,"195.34.89.241",7,2,"AB"	Read back 2 bytes from socket ID 0.
AT+USOCL=0	OK	Close socket ID 0.

¹ For more details, see appendix B5 in SARA-R4 series AT commands manual [2].

8.5.3 SIM Issuer Identification Number detection

 This section is only applicable to the SARA-R410M-63B product version.

The SARA-R410M-63B product version features a SIM-lock-like mechanism that only enables the radio functionality when a valid SIM card is inserted.

Upon boot, the module will read the Issuer Identifier Number (IIN) from the SIM:

- If the IIN is a valid SIM listed in the internal database, it will then automatically set the MNO profile followed by a module reset to allow the profile to take effect.

Once the MNO profile has been set according to the SIM as described in the above process, then if the SIM should change from one carrier to another (i.e., SoftBank SIM to DoCoMo SIM), the module will repeat the above process.

See [Table 4](#) for IIN values stored in lookup database.

 For SARA-R410M-63B-00, the firmware IIN internal database was populated on October 2019. This database includes both MNO and MVNO (Mobile Virtual Network Operator) SIMs.

8.6 Roaming factors

8.6.1 Higher priority PLMN scan when roaming

When the module is registered to a network as a roaming device, and the SIM meets all the following conditions, then the module will execute a Higher Priority PLMN scan when the scan timer expires (this timer can be as low as 2 minutes, as it depends on the internal value):

- Enables a Higher Priority PLMN scan associated with a scan timer value.
- There is an OPLMN (Operator Controlled Public Land Mobile Network) list.
- One entry in the OPLMN list has the same MCC (Mobile Country Code) as the current registered PLMN.

If the host uses data services for more than the timer value, then the data call can be interrupted and dropped when the scan timer expires and RRC connection is released in order to transition to the scan process. In such a case, the host must wait for the device to reestablish registration on a valid network with service. The host will then need to setup a new data service session; the previous data session will not resume.

If the host wishes to avoid interruption of such a Higher Priority PLMN scan, then manual PLMN selection with +COPS AT command (<mode>=1, manual mode) can be used.

Other notes and key points:

- AT+COPS=0 command always triggers a high priority PLMN search and performs a full PLMN scan.
- In +COPS: 2 mode the module radio/cell state is retained. This means that power consumption will be higher than in +CFUN: 0 as the module will keep on searching for the most suitable cell.
- The AT+COPS=2 / AT+COPS=0 cycle is to be used when High Priority PLMN search has to be triggered (for example, in roaming conditions), while AT+CFUN=0/1 cycle shall be used to trigger a registration cycle.

8.6.2 Data enable/disable roaming feature

SARA-R4 series modules provide the means to disable PDP context when roaming with the +UDCONF=76 AT command. Some MNO carriers may require this feature to be enabled, which is disabled by default.

Example on how to enable this feature.

Command	Response	Description
AT+UDCONF=76, 1, 1	OK	Set data flag high to enable "Disable data when roaming".
AT+CFUN=15	OK	Reboot the module for the mode to take effect.
AT+UDCONF=76	+UDCONF: 76, 1, 1 OK	Read to confirm data flag set. The PDP will now not be able to send data when roaming on a network.

8.7 Booting up in offline state

 This section is applicable to SARA-R410M-02B-03 and SARA-R412M-02B-03.

When booting-up the module in offline mode such as in airplane mode (+CFUN: 4), then to avoid a potential conflict with LwM2M leading to an unexpected module reboot, it is recommended to set disable LwM2M before exiting the airplane mode by setting the module to full functionality to MT (+CFUN: 1). Following exit, reboot the module to restore LwM2M client.

Command	Response	Description
		Device boots-up in airplane mode.
AT+CFUN?	+CFUN: 4 OK	Confirm device is in airplane mode.
AT+ULWM2M=1	OK	Shutdown LwM2M client for this session.
AT+CFUN=1	OK	Set MT to full functionality from airplane mode.
AT+CFUN=15	OK	Reboot the module this way LwM2M will resume upon boot.

9 Data delivery

SARA-R4 series modules support three different data delivery modes: IP, NON-IP (using either control plane or user plane) and SMS.

To configure for IP or NON-IP, the host application must configure a PDP context using the `+CGDCONT` AT command.

To send NON-IP data the host application must use the `+CSODCP` AT command. To receive NON-IP data the host application must configure the data reporting URC with the `+CRIDCP` AT command. See section 17 for further information.

9.1 Data planes

SARA-R4 series modules currently support for Cat M1 S1-User Plane data transfer and for NB-IoT supports S1-Control Plane Clot EPS Optimization.

9.2 Attach types

Use the `+USVCDOMAIN` AT command to specify how the SARA-R4 series modules attach to the network if the default attach type is not supported by the network.

All USA MNO profiles use Combined Attach (CS & PS).

All Europe MNO profiles have Attach Type set to EPS only (PS).

10 PDP context / Access Point Name (APN)

10.1 Default APNs

When using the `+UMNOPROF` AT command, a pre-defined APN may be set for the specified network. For more details, see the section [7.1](#).

To automatically obtain the default APN from the (non-roaming) network, the module must have a blank quoted string "" APN configured when using the `+CGDCONT` AT command. When the module attaches, the network will provide the default APN for the activated PDP context.

Generally, if using a roaming SIM, the host will have to provide a specific APN, provided by the network operator the roaming SIM was from.

 On the DoCoMo MNO profile of the SARA-R410M-63B product version, the APN must be manually entered to register with the DoCoMo network.

10.1.1 Verizon attach APN

For the Verizon Wireless network (<mno>=3), the attach APN is configured to a void string in `+CGDCONT`. It is expected that the network provides Class 3 Data APN after attach, and this makes bearer at <cid>=1 available for user data transfer.

In any case the application processor shall treat the attach APN the same as the class 3 APN and route all internet traffic to this PDN, even if the provisioned APN name in the attach APN differs from the string available in the Verizon APN table. This behavior complies with Verizon Wireless requirement VZ_REQ_LTEB13NAC_6352.

Verizon Wireless does not allow the activation of two or more PDNs with the same APN string and IP type.

 On SARA-R410M-02B-03, when the Verizon MNO profile is selected (`+UMNOPROF: 3`), the module may not restore the last APN value to blank on CID1 after de-registering with network. It is recommended that the host monitors the APN value to see if it needs to restore the APN to blank, or change the APN if another APN is desired upon next registration, e.g., when a SIM, which uses different APN, is inserted.

10.2 Multiple & private APNs

The host must configure any private APNs using the `+CGDCONT` AT command. Only the default bearer (<cid>=1) will be activated when it attaches if multiple contexts/APNs are configured before the module attaches to the network. The host must activate the other contexts/APNs by using the `+CGACT` AT command.

 On SARA-R4 "02B" product versions, only one PDP context can be active. Before another PDP context can be activated the host application must deactivate the current PDP context.

10.3 Authentication

The authentication on APNs can be configured by using the `+UAUTHREQ` AT command.

```
AT+UAUTHREQ=<cid>,<authentication_type>,"password","username"
```

 The password comes before the username.

The host can set authentication parameters for each PDP context configured with `+CGDCONT`. It must specify CHAP, PAP or none.

11 DUN/PPP

When a data call is initiated by means of the `D*` AT command, the module switches to the PPP mode just after the CONNECT intermediate result code. The first step of the PPP procedure is the LCP handshake. SARA-R4 modules will first request the CHAP authentication during LCP negotiation.

- The host can respond with null (empty) username and null (empty) password.
- If the host PPP rejects (Configure-Reject) authentication during any LCP phase, SARA-R4 does not request any more authentication.
- If the host PPP NACKs (Configure-NAK) CHAP authentication during LCP negotiation, SARA-R4 will then request PAP authentication.
- If the host PPP NACKs (Configure-NAK) PAP authentication during LCP negotiation, SARA-R4 will request No Auth.

Using dial command for establishing PPP connection: `ATD*99***1#` the '1' in this example refers to the first active PDP context returned by the `+CGDCONT` read command.

-  For SARA-R410M-02B-00 and SARA-R410M-52B-00, to avoid conflict with the internal uFOTA client service, the PPP operation should be entered within 30 s of the module boot. If the DUN/PPP (`ATD#99`) establishment fails, the application should retry.
-  For SARA-R410M-02B-04, SARA-R410M-02B-03, SARA-R410M-02B-02, SARA-R410M-02B-01, SARA-R410M-52B-01, SARA-R410M-52B-02, SARA-R412M, and SARA-R4 "63" / "73" / "83" product versions the uFOTA client starts earlier from boot and therefore in contrast to previous firmware it should be attempted 30 s after the module boot.
-  If the LWM2M LifeTimer should expire during the middle of the module's run time after boot a DUN/PPP establishment will fail, and the application should retry.
-  In regard to device security and data security for SARA-R4 "63" / "73" / "83" product versions, a PPP/DUN call cannot be established when:
 - The device attempts to connect to the u-blox security server to perform a bootstrap
 - When a security heartbeat time expires and it attempts to connect to u-blox security service server
 - When the encryption / decryption feature attempts to connect to owner's platform.

The DUN call should be retired if any of the above cases should be encountered.

For more details on device security and data security, see u-blox IoT Security-as-a-Service overview [\[10\]](#).

For 2G RAT, on the SARA-R412M the PDP context will be activated by the uFOTA client and released by the uFOTA client when the data call to the uFOTA server is complete. During this time, the PDP context cannot be activated by the host via `+CGACT` nor can it deactivate the context that is established by the uFOTA client. The host needs to monitor the PDP context upon the boot and start the DUN call when the PDP context is not activated and available to be used.

-  After the module has attached to the network the host can control the PDP context APN, authentication and MTU sizes directly through PPP.
-  For Windows and non-Windows hosts, the `AT&S0` command is needed.

-  For Windows dial-up the command `ATX0` should be configured as the initialization string under advanced properties of the modem.
-  If the network throughput is less than the data sent from the host to the module (is limited by uplink network resource/bandwidth), then a packet data loss may occur, even with hardware flow control enabled. To avoid this issue do either or both:
 - Reduce the baud rate used
 - The host application can slow down data transfer by adding pauses between data payloads or breaking up their payload and adding delay.
-  When using MUX and PPP combined, toggling the DTR line does not terminate the PPP session and return the device to the command mode. In this configuration, it is recommended that the host terminates the PPP session, which can be done by sending `LCP_TERM REQ`. Another method to terminate the PPP session is to send a MSC MUX frame for logical DTR de-assert.

If the PSM is enabled and the device goes into RRC idle state due to inactivity of traffic over the PPP link, the device will enter the PSM low power mode when the T3324 timer expires.

11.1 PPP over multiple PDP contexts

Optionally, a second PDP context can be set up for PPP if used with multiplexer (multiplexing mode MUX) over the UART serial port. In such a configuration, the socket type data calls established by AT commands and internal embedded calls are only routed through the default context CID1.

-  A different and unique APN is required per context.

In the below example there are two contexts defined and established. The second context on CID2 may be utilized by PPP. Do not activate the second context manually, instead establishing the PPP session will automatically activate and deactivate it. In the example the second context is activated by the PPP session.

Example of a second context for PPP dial up connection:

```
+CGDCONT: 1,"IP","APN1","166.130.71.189",0,0,0,0
+CGDCONT: 2,"IPV4V6","APN2","10.117.32.103 38.0.3.128.178.65.129.209.0.0.0.74.87.68.176
.1",0,0,0,0
```

For more details on multiple PDP contexts, see the SARA-R4 series AT commands manual [\[2\]](#).

12 Monitoring module status

12.1 Registration status

The module must be attached to an LTE Cat M1 or an NB-IoT network in order to allow the host to send or receive any messages.

To check the network registration status, issue the `+CEREG` read command (`+CGREG` for 2G registration). The second parameter of the response provides the registration state.

- 0: the MT is not registered, and it performs a network scan through all enabled RATs
- 1: registered
- 2: not registered, but currently in the process to.
- 3: registration denied. The application should have a re-try mechanism which does not simply try registration immediately, but has some back-off process
- 4: unknown
- 5: registered, roaming

If the SIM used is an international SIM (roaming SIM) then the registration process can take many minutes for the first time. Once the module is registered on that network the PLMN should be stored in the SIM to allow quicker registration next time. The application can tell if it is using roaming SIM by the state being “5: Registered, roaming”.

The `+CEREG` URC can be enabled to provide the network registration status. Depending on the `<mode>` parameter it is possible to configure the parameters of interest. For more details, see SARA-R4 series AT commands manual [2].

 Setting the `+CEREG <mode>` parameter to 3, 4 or 5 it is possible to see the registration EMM cause value. These values are described in the 3GPP TS 24.008 [13]. Typical causes:

- #5 IMEI not accepted
- #11 PLMN not allowed
- #12 Location area not allowed
- #13 Roaming not allowed in this location area
- #22 Congestion

12.2 Viewing IP address

Before sending any IP data to the LPWAN network configure the device with an IP address.

 Use the `+CGPADDR` AT command to read what the IP address of the module has been set to.

The `+CGDCONT` AT command lists the IP addresses for each defined PDP context.

No IP addresses are displayed until the module has registered on the network and has been provided with an IP address. The application could simply poll this IP address to see when the entire registration process has finished.

12.3 Viewing DNS address

For using domain names, and for uFOTA client to operate, the module must have received a DNS IP address. Use the `+CGCONTRDP` AT command to view if the module has been assigned a DNS IP address.

 Without a DNS address being assigned to the module by the network, uFOTA client will not operate.

12.4 AT example

Below is example pseudo code that shows how to manage the registration process in the host application.

Because the +COPS AT command does not provide a URC when the Radio Access Technology (RAT) changes on registration, the host application should wait for “any” registration, and then read the RAT from the +COPS <AcT> parameter:

```
// (assuming the module is not connected and not scanning i.e., +COPS: 2)

// Enable URCs
AT+CEREG=1
AT+CGREG=1
AT+CREG=1

// Start auto cell scanning/registration (it could be AT+COPS=1,2,"<plmn"> too)
AT+COPS=0

While not registered
  <Wait for URC>
  If URC = +CEREG: 1 or +CEREG: 5 or +CGREG: 1 or +CGREG: 5 then
    AT+COPS?
    RAT = <AcT> parameter

    // Module will only be registered on either LTE or GPRS,
    // so once these URCs return '1' or '5', exit the loop
    Registered = true
  End if
Loop

// If GPRS, then activate the PDP context (it is not automatic)
If RAT = '3' then AT+CGACT=1

// Wait for PDP context to become active
While not PDP_context_active
  If AT+CGACT? = '1'
    PDP_context_active = true
Loop

// Module is now registered and has an active PDP context.

// read the IP address
AT+CGPADDR
```

13 TCP/UDP sockets

Basic communications to servers can be made using UDP or TCP. The host application will need to create a socket, and through the socket send and receive data. Multiple sockets can be used at the same time.

-  If the module changes RAT any sockets opened at the time will be closed.
-  Any open sockets will be kept open if the module loses the previous cell and can camp on another cell without timing out scanning for the new cell.

13.1 Packet switched data configuration – IPv4/IPv6

SARA-R4 module series defines a single profile for the packet switched data for the internal IP stack. Because there is only one profile, this is handled automatically.

-  IPv4 is configured by default. If the host application is using IPv6, it must modify the IP type parameter by means of the `+UPSD` AT command.

Command	Response	Description
<code>AT+UPSD=0,0,1</code>	OK	Set profile 0, protocol IP type to IPv6

13.2 Domain name addresses

If the network has not assigned a DNS IP address to the module the socket commands will not work with domain names, only IP addresses.

Check the PDP context dynamic parameters using the `+CGCONTRDP` AT command. Here it will list the primary and secondary DNS address.

13.2.1 DNS caching

A resolved DNS Resource Record (RR) is locally cached based on the TTL value sent by the DNS server. There can be a maximum of 5 entries in the DNS cache. When the maximum entries have been reached, then new entries will be added, while the oldest entry is removed.

The DNS entry will be added if the TTL value is within the constraint of:

- A maximum TTL allowed is 86400 s
- A minimal TTL allowed is 5 s.

Any TTL value outside the above constraint limits will not be cached.

13.3 Socket buffers

SARA-R4 series modules have transmit and receive buffers for the data sent on the socket. These buffers allow the host application to send and receive data while the module is performing its own communication with the cell.

- TCP RX total buffer: 16 kB
- TCP RX window: 16 kB
- TCP TX buffer for each socket: 10 kB
- UDP buffer: 16 kB

13.4 Creating a socket

Create a socket to be able to send UDP data. A socket ID is returned.

Command	Response	Description
AT+USOCR=17	+USOCR: <socketID>[,<listen_port>] OK	Create a UDP socket. Returns the socket ID to be used with other socket commands.

- For UDP it is possible to specify the listen port with the create socket command. If the listen port is specified here, there is no need to use the +USOLI AT command. An error result code will be returned if both procedures are tried.

13.5 Closing a socket

Once a socket is no longer needed, it should be closed.

Command	Response	Description
AT+USOCL=<socketID>[,<async>]	OK	Specify the socket ID to close.

It is possible to set the <async> parameter which allows the AT command to complete with the final result code before the socket has actually closed. If the optional <async> parameter is used the +UUSOCL URC will be issued when the socket has finally closed.

- Issue the +USOCLCFG AT command to enable or disable the closing of the TCP socket on the remote system when the module is in idle mode. If enabled the module will re-establish the RRC connection and send a message to the server closing the socket. When this is disabled the module will leave the server's socket open when it goes into idle mode.
- The +UUSOCL URC will not be issued if the remote host closes the socket until all the received data has been read using the +USORD AT command.

Per TCP RFC 793 [17], the client can specify a "TIME_WAIT" value, commonly named as linger timer, for the above socket closing process. Lowering this value could reduce the socket closure time, but by doing so it would trade off time to ensure the last ACK is sent from the client to the server, where in context the client is referred to as the initiator of the TCP session and the receiver is the server.

For SARA-R410M-02B-00, SARA-R410M-02B-01, SARA-R410M-52B-00, SARA-R410M-52B-01, SARA-R412M-02B-00, SARA-R412M-02B-01, and SARA-R4 "63/73/83" product versions, the linger timer default value is 30 s.

13.6 UDP

The UDP is a basic way of sending a message to an application server. There are no transport layer acknowledgements for the message and there is no guarantee the message will arrive at the destination. To add acknowledgements to these messages consider using CoAP messaging externally on the MCU. A connection to a server is not needed when using UDP as the SendTo function contains all the information required.

13.6.1 Sending data

Sending data to an external server is as simple as specifying the socket to use, the remote IP address and port, and then the length of data, plus the data. The information text response provides the number of bytes successfully sent.

- The maximum length of data that can be sent at a time is 1024 bytes.

Command	Response	Description
AT+USOST=<socketId>,"<remote_address>",<remote_port>,<length>,"<data>"	+USOST: <socketId>,<length> OK	Send data to the specified IP address and port through the socket noted by the ID.

For direct link with UDP, if the network throughput is less than what the module is attempting to send (is limited by uplink network resource/bandwidth), then a UDP packet data drop may occur, even with hardware flow control enabled. To avoid this issue, do either or both:

- Reduce the baud rate used
- The host application can slow down data transfer by adding pauses between data payloads or breaking up their payload and adding delay

13.6.2 Receiving data

The data reception is performed in two steps. If the module has received data from the network on a socket that is listening, then a URC is given. From this message, the application can read the data on the appropriate socket and length.

13.6.2.1 Data arrived indicator

Command	Response	Description
	+UUSORF:<socketId>,<length>	This message is provided to tell the application how much data is available to read on the specified socket.

The application should read this message and then read the data from the specified socket.

13.6.2.2 Reading data from socket

The data reception is performed by means of the +USORF command, using the information given in the +UUSORF URC.

Command	Response	Description
AT+USORF:<socketId>,<length>	+USORF:<socket>,"<ip_addr>",<port>,<length>,"<data>" OK	Provides the received data to the application.

13.6.3 Testing

A simple way to test UDP sockets over the NB-IoT network is to send data to an echo server.



The u-blox echo server is echo.u-blox.com at IP address 195.34.89.241 on port 7.

Here is an example:

Command	Response	Description
AT+USOCR=17	+USOCR: 1 OK	Create a socket. The socket ID is 1.
AT+USOST=1,"195.34.89.241",7,5,"48656c6c66F"	+USOST: 1,5 OK	Send "Hello" to u-blox echo server. Sent 5 bytes on socket ID 1.
	+UUSORF:1,5	Received 5 bytes on socket ID 1.
AT+USORF=1,5	+USORF: 1,195.34.89.241,7,5,"48656c6c66F" OK	Read 5 bytes on socket ID 1. Received data information provided... "Hello".

13.7 TCP

TCP uses transport acknowledgments between the module and the destination server. TCP will automatically resend any lost packets and therefore is more robust than UDP.

The downside to using TCP is that there are more messages to be sent between the UE and network and therefore will consume more power.

13.7.1 Connecting to server

After creating the socket the host application needs to 'connect' to the server. This connection is kept open until the socket is closed.

Use the `+USOCO` AT command to connect to the remote host where the remote address, remote port is specified.

13.7.2 Writing socket data

Use the `+USOWR` AT command to write data to a socket, and hence to the remote host connected to. The module will respond with the number of bytes queued. If the internal buffer is full an error result code will be returned. Issue the `AT+USOCTL=1` command to get the last error.

13.7.3 Receiving data

When data is received from the remote host the `+UUSORD` URC will be issued. Use the socket and length parameters of this URC to read the data back from the module to the host application with the `+USORD` AT command.

14 MQTT

SARA-R4 series modules can be configured to quickly and easily run the MQTT protocol. This section provides the minimum configuration required to get the MQTT protocol up and running. There are two different quick start techniques that can be used to quickly get to an MQTT connection (and performing MQTT commands):

- Minimal MQTT configuration – it accepts the default values provided for MQTT configuration
- Saved MQTT configuration – it changes the MQTT configuration until it is acceptable and saving it, thus allowing a quick restore to get back all of the MQTT configuration parameters

14.1 Quick start based on minimal MQTT configuration

u-blox's MQTT implementation supplies a default value for a lot of MQTT's configuration parameters. However, the MQTT server (i.e., MQTT message broker) has no default value and must be specified in order to connect. Depending on the configuration of the MQTT server, an MQTT connection might be possible after specifying only the MQTT remote server information. If the MQTT server requires login credentials (i.e., username and password), then the username and password must also be configured in order to create an MQTT connection.

14.1.1 Restore MQTT to factory-programmed setting

The following command restores factory-programmed parameters to MQTT:

```
AT+UMQTTNV=0
```

-  This will overwrite all the MQTT profile parameters currently in the NVM.
-  Do not execute this command if there is current active MQTT login connection. Otherwise, the MQTT profile parameters for that connection will be lost.

14.1.2 MQTT client ID specification

When MQTT factory-programmed setting has been restored the client ID should be checked and/or if needed set manually:

```
AT+UMQTT=0,"<unique client ID>"
```

14.1.3 MQTT remote server specification

The MQTT server can be configured using either an IP address or a name.

14.1.3.1 Server IP address

The following command specifies the remote MQTT server's IP address:

```
AT+UMQTT=3, "127.0.0.1"
```

Where the actual server's IP address substitutes for the "127.0.0.1" placeholder in the example above.

14.1.3.2 Server name

The following command specifies the remote MQTT server's name:

```
AT+UMQTT=2, "www.mqttbroker.com"
```

Where the actual server's name substitutes for the "www.mqttbroker.com" placeholder used in the example above. The module will use its internal DNS client for IP address resolution.

14.1.4 MQTT connection

Using the above configuration, an MQTT connection can be attempted.

```
AT+UMQTTTC=1
```

The command could be used to attempt to make an MQTT connection with the specified MQTT remote server. If the connection is successful, depending on the product version, the MQTT remote server will send either:

```
+UUMQTTTC: 1,0      for SARA-R4 "02" / "52" product versions
+UUMQTTTC: 1,1      for SARA-R4 "63" / "73" / "83" product versions
```

This indicates a successful login to an MQTT connection. Any non-zero connection result indicates the MQTT server refused the MQTT login connection. Once an MQTT connection is established, MQTT commands are available.

14.1.5 Additional configuration

Either the MQTT server could require additional (non-default) MQTT profile parameters or the user might prefer different, non-default parameters. Section 14.4 covers different MQTT profile parameters that might be required for an MQTT login connection.

14.2 Quick start based on saved NV configuration

The second quick start technique involves performing the MQTT configuration parameter setting before and saving them to NVM (see section 14.2.1). Once a valid set of MQTT client profile parameters are saved, the user can restore them from NVM by means of AT commands and perform an MQTT login to create an MQTT connection.

 The MQTT remote server must be specified (either by IP address or name) in the saved NVM configuration for a connection to occur.

14.2.1 Restore from saved NVM - MQTT profile

The following command restores all the previously saved MQTT profile parameters from NVM:

```
AT+UMQTTNV=1
```

 This will overwrite all the MQTT profile parameters currently in memory, so it should not be performed if there is currently an active MQTT login connection (since the MQTT profile parameters for that connection will be lost). The restored MQTT profile parameters were previously saved using the `AT+UMQTTNV=2` command.

14.2.2 MQTT connection

Using the above configuration, an MQTT connection can be attempted. The following command attempts to make an MQTT connection with the MQTT remote server (specified by the saved NVM MQTT configuration):

```
AT+UMQTTTC=1
```

If the connection is successful, depending on the product version, the MQTT remote server will send one of these URCS:

```
+UUMQTTTC: 1,0      for SARA-R4 "02" / "52" product versions
+UUMQTTTC: 1,1      for SARA-R4 "63" / "73" / "83" product versions
```

This indicates successful login to an MQTT connection. Any non-zero connection result indicates the MQTT server refusing the MQTT login connection. Once an MQTT connection is established, MQTT commands are available.

14.3 Connection commands

Once an MQTT login connection is established, the following commands can be sent to the MQTT server: subscribe, unsubscribe, publish, read messages, and logout. An MQTT client connected to an MQTT server can decide whether to publish messages to the MQTT server or subscribe to message reception from the MQTT server or both (publish and subscribe). An MQTT client could even choose to subscribe to a topic filter that includes the topic names to which the MQTT client publishes messages.

14.3.1 Subscribe to MQTT topic filter

The following command subscribes a connected MQTT client to a given topic filter:

```
AT+UMQTTTC=4,<max_QoS>,<Topic Filter>
```

After the MQTT client receives a:

```
+UUMQTTTC: 4,<reason>,<QoS>,<topic_name>
```

for that <Topic Filter> (indicating the MQTT server successfully subscribed the MQTT client to the given <Topic Filter>), the MQTT server will send to the MQTT client every published message that matches the given <Topic Filter>.

14.3.1.1 Example

The following command subscribes the MQTT client to all messages published that match the "/user/ublox" Topic Filter:

```
AT+UMQTTTC=4,0,"/user/ublox"
```

14.3.2 Publish MQTT message to topic name

The following command sends an MQTT message to the MQTT server with a given Topic Name:

```
AT+UMQTTTC=2,<max_QoS>,<retain>,"<Topic Name>","<Message>"
```

The MQTT server will send that MQTT message to every MQTT client connected to it that is subscribed to a topic filter that matches the given topic name.

14.3.2.1 Example

The following command publishes the "Hi! ..." message to all the MQTT clients connected to the given MQTT server whose topic filter subscriptions match the "/user/ublox" topic name:

```
AT+UMQTTTC=2,0,0,"/user/ublox","Hi! This is an MQTT message."
```

14.3.3 Read MQTT messages received

Upon receiving an MQTT message, the MQTT client will receive an asynchronous notification (URC) of the reception of an MQTT message with the following format for

SARA-R4 "02" / "52" product versions:

```
+UMQTTTCM: 6,<Num_unread_msgs>
```

SARA-R4 "63" / "73" product versions:

```
+UMQTTTC: 6,<Num_unread_msgs>"
```

After receiving the above notification, the host application can send the `AT+UMQTTTC=6` read command to list the stored messages. The URC will be issued again, then the topic/message pairs.

SARA-R4 "02" / "52" product versions:

```
AT+UMQTTTC=6
+UMQTTTC: 6,1
```

```
OK
+UMQTTTCM: 6,<Num_unread_msgs>
<topic_name>
<message>
<topic_name>
<message>
...
OK
```

 The format of the message output can be configured with `AT+UMQTTTC=7,<format>` command.

On SARA-R4 "63" / "73" product versions, the read command syntax is:

```
AT+UMQTTTC=6[,<one_message>]
```

Set the `<one_message>` parameter to the recommended value of 1 reads one received message at a time:

```
AT+UMQTTTC=6,1
+UMQTTTC: 6,<QoS>,<topic_msg_length>,<topic_length>,<topic_name>,<read_msg_length>,<read
_msg>
OK
```

14.3.4 Logout

The following command terminates the MQTT connection:

```
AT+UMQTTTC=0
```

After this command is issued, the MQTT connection to the MQTT remote server no longer exists. Therefore, no MQTT commands (e.g., publish or subscribe) will work until another MQTT connection is established.

14.4 Profile parameters

14.4.1 Login credentials

If the MQTT server requires login credentials (i.e., username and password) to make an MQTT connection, the following command provides the required login credentials:

```
AT+UMQTT=4, "<Username>", "<Password>"
```

Where the actual <Username> and <Password> replace the <Username>/<Password> placeholders used in the example.

14.4.2 Client ID

The module attempts to create a default client ID for each module attempting to connect to an MQTT server, uniquely based on the module's IMEI. It is important that this client ID is unique. Upon receiving a new login connection, an MQTT server must disconnect any pre-existing connection using the same client ID. Users may decide to create their own proprietary naming scheme to uniquely identify each of their MQTT client modules. The following command specifies an MQTT client ID that must be unique to the MQTT server:

```
AT+UMQTT=0, "<Unique_Client_ID>"
```

Where the actual client ID designation replaces the <Unique_Client_ID> placeholder used in the example. The user may also be required to supply the client ID if the module fails to access its IMEI and thus fails to create a default client ID.

14.4.3 “Will Message” configuration

The MQTT protocol allows each MQTT connection to assign a will message to be sent when the MQTT server involuntarily disconnects an MQTT client. Configuring a will message requires four parameters: will message, will topic, will QoS, and will retain. The following command defines the <Will_QoS>, <Will_Retain>, and <Will_Topic> parameters:

```
AT+UMQTTWTOPIC=<Will_QoS>,<Will_Retain>,"<Will_Topic>"
```

This command defines the <Will_Message> parameter:

```
AT+UMQTTWMSG="<Will_Message>"
```

Both of these commands are necessary to define a valid will message for the MQTT client.

14.4.4 List of MQTT profile parameters and AT commands to set them

<Parameter>	Meaning	Resulting from the following commands
CleanSession ²	Whether session state survives across MQTT disconnects	AT+UMQTT=12,<CleanSession>
Client ID	Uniquely identifies MQTT client to MQTT server	AT+UMQTT=0, "<Client_ID>"
Client port ²	Local client's TCP port number	AT+UMQTT=1, "<Port_Number>"
Inactivity timeout	MQTT server times out MQTT client if this timeout is exceeded with no activity (also called KeepAlive Duration)	AT+UMQTT=10,<Inactivity Timeout>
Username	Login credentials when connecting to an MQTT server	AT+UMQTT=4, "<Username>", "<Password>"
Password	Login credentials when connecting to an MQTT server	AT+UMQTT=4, "<Username>", "<Password>"
Server IP address	Specifies the IP address of the MQTT remote server	AT+UMQTT=3, "<Server IP Addr>"
Server name	Specifies the name (to be resolved by DNS into an IP Address) of the MQTT remote server	AT+UMQTT=2, "<Server Name>"

² Not supported on SARA-R4 "63" / "73" product versions

15 HTTP

HTTP profiles are used to define the remote server. The basic HTTP profile consists of a server name or IP address and basic authentication (username, password). For HTTPS, the server private certificate can be specified with USECMNG.

15.1 HTTP with server name only

Example of HTTP with basic server name only:

Command	Response	Description
AT+UHTTP=0,1,"google.com"	OK	Set the server name for the profile 0.
AT+UHTTTPC=0,1,"/", "get.rsp"	OK	Profile 0, GET request of the default page to file <code>get_rsp</code> .
	+UUHTTPCR: 0,1,1	The +UUHTTPCR URC notifies the success/failure of the operation (in this example: success).
AT+URDFILE="get.rsp"	+URDFILE: "get.rsp",737,"HTTP/1.0 OK	Read the file.

15.2 HTTP with basic authentication

Example of HTTP with basic login and password credentials for authentication:

Command	Response	Description
AT+UHTTP=1,0,"123.123.123.12"	OK	Set the server IP address for the profile 1.
at+UHTTP=1,2,"someusername"	OK	Set the username.
at+UHTTP=1,3,"somepassword"	OK	Set the password.
at+UHTTP=1,4,1I j	OK	Set the authentication type.
AT+UHTTTPC=1,1,"/", "get.rsp"	OK	Profile 1, GET request of the default page to file <code>get_rsp</code> .
	+UUHTTPCR: 1,1,1	The +UUHTTPCR URC notifies the success/failure of the operation (in this example: success).
AT+URDFILE="get.rsp"	+URDFILE: "rsp_file",967,"HTTP/1.0 1 200 OK OK	Read the file.

15.3 HTTPS with SSL/TLS security certificate

For HTTPS to access a server with SSL/TLS security certificate, the host needs to configure the security profile with the certificate that has been imported to the module. See section 16 for more details about the certificate import process.

In this example, the “<https://www.u-blox.com>” server site is used with a root certificate.

Command	Response	Description
AT+USECMNG=3	"CA","rootCA","SwissSign Silver CA - G2","2036/10/25 08:32:46" OK	List of certificates.
AT+USECPRF=2	OK	Configure Security Profile ID 2.
AT+USECPRF=2,0,1	OK	Set TLS validation to 1.
AT+USECPRF=2,1,3	OK	Use TLS v1.2.
AT+USECPRF=2,3,"rootCA"	OK	Set certificate as rootCA.
AT+UHTTP=0,1,"www.u-blox.com"	OK	Set HTTP profile and server name.
AT+UHTTP=0,6,1,2	OK	For HTTP profile 0, enable the security option with USECPRF ID 2.
AT+UHTTPC=0,1,"/","get.rsp"	OK	Profile 0, GET request of the default page to file <code>get_rsp</code> .
	+UUHTTPCR: 1,1,1	The +UUHTTPCR URC notifies the success/failure of the operation (in this example: success).
AT+URDFILE="get.rsp"	+URDFILE: "rsp",852,"HTTP/1.1" OK	Read the file.

16 Secure data

16.1 Certificate format

SARA-R4 series modules do not support the PEM format. Only DER and CER formats are supported. For a useful reference on how to convert certificates from PEM format, see the support SSL website.

For an example of using OpenSSL application to convert PEM to DER:

```
openssl x509 -in cert.crt -outform der -out cert.de
```

16.2 DTLS client

The SARA-R4 DTLS client provides an end-to-end secure data transfer over UDP sockets. With DTLS, UDP datagram should be as good as TCP in terms of packet loss, retransmission, and packet reordering.

 For more details on DTLS, see RFC 6347 [16].

16.2.1 AT commands examples for DTLS client

Command	Response	Description
AT+USOCR=17	+USOCR: 0 OK	Create a UDP socket.
AT+USECPRF=0,8,"PSK"	OK	Configure PSK.
AT+USECPRF=0,9,"PSK ID"	OK	Configure PSK ID.
AT+USECPRF=0,2,0	OK	Configure the root certificate.
AT+USOSEC=0,1,0	OK	Enable secure socket.
AT+USOCO=0,"172.126.88.3",8447	OK	Connect the socket.
AT+USOWR=0,10,"1234567890"	+USOWR: 0,10 OK	Sends encrypted data over UDP socket with DTLS session enabled: text format
AT+USOWR=0,10	> +USOWR: 0,10 OK	Sends encrypted data over UDP socket with DTLS session enabled: binary format.
	+UUSORD: 0,10	
AT+USORD=0,10	+USORD: 0,10,"1234567890" OK	Read the decrypted data.
AT+USOCL=0	OK	Disconnects DTLS and close the socket.

17 Non-IP messaging

Using the Non-IP method of sending and receiving messages saves the overhead of needing to send a UDP IP header. The UDP header is about 48-60 bytes in length, and so an application sending 100 bytes will send about 160 bytes.

Customers cannot use Non-IP messaging without enablement via the MNO. This is because there is no destination IP address and therefore the MNO will either store these messages in their own IoT platform, or will forward these messages on to another service. Either way the customer needs to understand where these Non-IP messages will go.

To send a Non-IP message use the +CSODCP AT command.



Attach type must be set to EPS only for using the +CSODCP AT command.

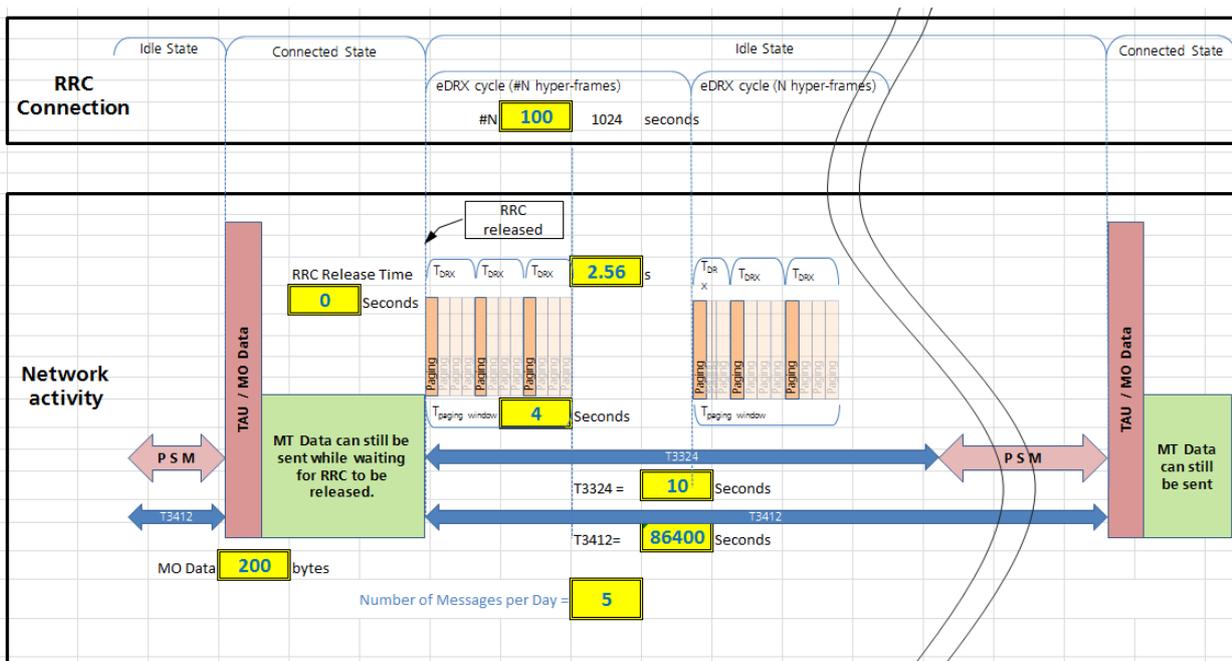
18 Paging, eDRX, PSM and deep sleep mode

The LTE Cat M1 or NB1 protocol allows for power save mode (PSM), and the SARA-R4 series modules also support a deep-sleep mode where the module is running at low current, ~8 μ A. The module automatically enters various states depending on the device activity. Here below are listed the common activities and the various states it will be in after registration.

1. The device is in Power Save Mode (PSM) and in deep-sleep; it is already registered and has nothing to do.
2. A message is queued or the TAU timer has elapsed.
3. The device re-connects to network and sends and receives data. This is in connected state.
4. The RRC connection is released by the network. It is now in idle state.
5. Within T3324 timer, paging happens as per network configuration.
6. Power Saved Mode is entered after T3324 has elapsed.
7. T3412 elapses and Traffic Area Update is triggered, or application sends more data.

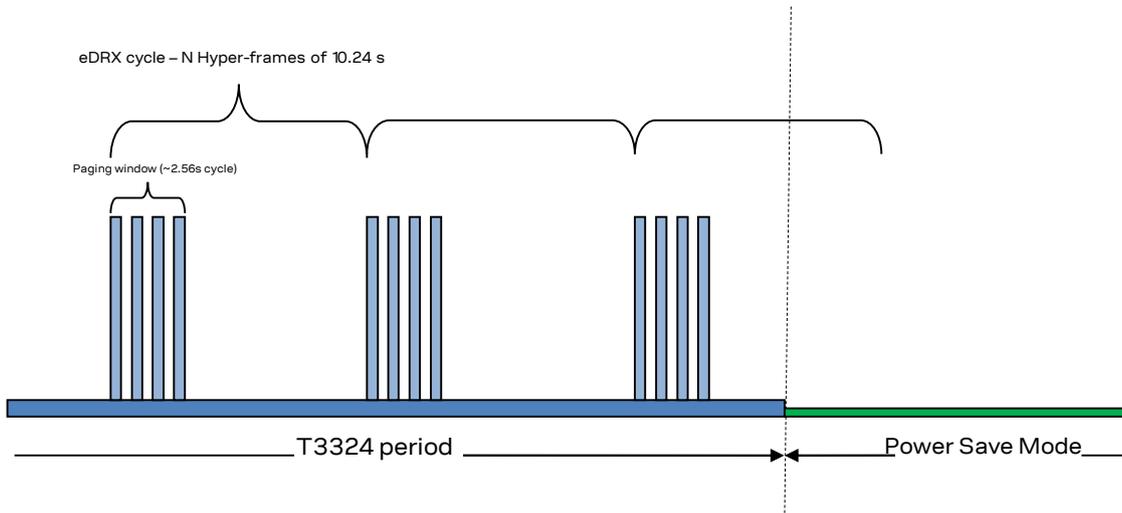
The module enters the deep sleep mode when there is no activity, it does not need to be in the PSM.

T3324 and T3412 timers are assigned by the network. The application can request to the network what timer values it wants, but the network does not need to grant these values.



18.1 eDRX

The 3GPP TS Release 13 introduced a new feature called Extended Discontinuous Reception (eDRX). This allows the paging to only operate for a period and then again sometime later. In between the paging windows the module is in deep sleep mode. eDRX operates while the T3324 timer is running and is specified by several hyper frames (10.24 s).



The module can still receive downlink messages when it is in the T3324 period. These messages will be cached by the network knowing the module will be awakened for the next paging window after the eDRX cycle has completed.

- If the eDRX state is changed by enabling or disabling eDRX via `+CEDRXS`, a `AT+CFUN=15` or proper shut-down/power-up should be applied for eDRX to properly function.
- The application can read the network eDRX value using the `AT+CEDRXRDP` command.
- The direct link mode for both sockets and FTP should not be used with HW flow control and eDRX all three combined together. This combination can lead to the module going into eDRX deep-sleep during active direct link data transfer session to due potential HW flow control timing leading to data not being able transfer smoothly and connection timeout.

18.2 Power save mode (PSM)

Power save mode is configured by means of the `+CPSMS` AT command. Two timers are specified, T3324 and T3412. These timers are for how long the module will be in active mode, and how long to wait until the next TAU event. After the T3324 timer expires the module will enter the Power Save Mode. In PSM the module is in deep-sleep mode and is only consuming approximately 8 μ A.

- When in PSM the module will not respond to AT commands.
- See sections [18.2.2](#) and [18.2.3](#) for how to set T3412 and T3324 values in `+CPSMS` AT command.

Power Save Mode (PSM) allows the device to skip the periodic page monitoring cycles between active data transmissions. During this implementation, the device becomes unreachable when the PSM is active, i.e., it will not be able to receive any downlink messages and any downlink messages sent from the customers cloud application will be lost.

By implementing the PSM, an LTE NB-IoT device can remain in PSM state for as long as 413 days, determined by the maximum value of the Tracking Area Update (TAU) timer.

During the PSM active state, all the HW components in the device are turned off, and the device will not monitor page messages or perform any Radio Resource Management (RRM) measurements. The only component that is running during PSM is the PMIC RTC.

PSM can enable more efficient low-power mode entry/exit, as the device remains registered with the network and its state maintained during PSM, without having the need to spend additional cycles to setup registration/attachment after each PSM entry/exit event.

On the SARA-R4 series modules, if the network supports PSM and grants PSM timers to the module upon attach process or Tracking Area Update (TAU), then the PDP context is retained across PSM cycles. Any PPP connections, sockets, or other connections must be re-established upon exiting the PSM. Since the module is essentially in the off state when it goes into the PSM, the behavior is similar to what would be expected if the module is turned off and turned it back on.

In practice, this makes sense because PSM cycles will typically be greater than 4 hours per GSMA guidance, so sockets likely will be closed on the server side due to inactivity.

Any settings the host application has made will need to be re-configured again after waking up the module. For example, ATE0, AT&S0, AT+CMEE, AT+CEREG. Only settings saved in the NVM according to the SARA-R4 series AT commands manual [2] are kept in PSM.

When the host is using either of the following data services:

- UDP or TCP sockets
- HTTP/HTTPS
- FTP/FTPS

the device can enter the PSM mode during the data service session, if there is an idle period of data transfer long enough for the network RRC timer to expire, thus releasing the RRC connection from the network.

 For non-data service features such as a download file by means of the +UDWNFILE AT command the device can enter the PSM during a file transfer.

To avoid interruption of the data service or other features from PSM, disable PSM via the +CPSMS AT command, execute the desired data service, and when finished, enable PSM with the +CPSMS AT command.

18.2.1 PSM with customized timer request

Command	Response	Description
AT+CMEE=2	OK	Enabling the verbose error.
AT+CPIN="1234"	OK	Activating the SIM card.  The SIM card needs to be active to enter the PSM.
AT+COPS?	+COPS: 0,0,"Verizon Wireless",7 OK	Confirming the module has been registered with the current carrier.
AT+CPSMS=1,,,"00011101","000010101"	OK	Enabling the PSM. Requesting customized timers.
AT+CFUN=15	OK	Reboot to enable the PSM.

18.2.2 T3412 timer (Periodic TAU)

Bits 5 to 1 represent the binary coded timer value. Bits 6 to 8 define the timer value unit for the GPRS timer as follows:

BIT	8	7	6	
	0	0	0	value is incremented in multiples of 10 minutes
	0	0	1	value is incremented in multiples of 1 hour
	0	1	0	value is incremented in multiples of 10 hours
	0	1	1	value is incremented in multiples of 2 seconds
	1	0	0	value is incremented in multiples of 30 seconds
	1	0	1	value is incremented in multiples of 1 minute
	1	1	0	value is incremented in multiples of 320 hours (Note 1)
	1	1	1	value indicates that the timer is deactivated (Note 2)

Example: "01000111" = 7 x10 hours = 70 hours

-  To allow the PSM to correctly function and allow the module to wake up for a TAU, the minimum recommended T3412 timer is 90 s, but timer values that are relatively short are not appealing for power consumption and typically not recommended.
-  NOTE 1: This timer value unit is only applicable to the T3312 extended value IE and the T3412 extended value IE (see 3GPP TS 24.301 [14]). If it is received in an integrity protected message, the value shall be interpreted as multiples of 320 hours. Otherwise, the value shall be interpreted as multiples of 1 hour.
-  NOTE 2: This timer value unit is not applicable to the T3412 extended value IE. If this timer value is received, the T3412 extended value IE shall be considered as not included in the message (see 3GPP TS 24.301 [14]).

18.2.3 T3324 timer (Active Time)

Bits 5 to 1 represent the binary coded timer value. Bits 6 to 8 define the timer value unit for the GPRS timer as follows:

BIT	8	7	6	
	0	0	0	value is incremented in multiples of 2 seconds
	0	0	1	value is incremented in multiples of 1 minute
	0	1	0	value is incremented in multiples of deci-hours
	1	1	1	value indicates that the timer is deactivated

Example: "00100100" = 4 x1 minute = 4 minutes

18.2.4 PSM modes

On SARA-R4 series modules there are two PSM modes supported, which are:

1. PSM with network coordination: For this mode, if the network grants the use of PSM, the module will then use PSM with context retention following the granted timers in coordination with network.
2. PSM without network coordination: In this mode, the module enters PSM by detaching from the network and does not retain context.

The +UPSMVER AT command allows reconfiguration of the above to either:

- Set AT+UPSMVER=4 to enable PSM with network coordination only.
- Use PSM without network coordination as a fallback solution when PSM is not supported by the network (+UPSMVER: 15 that is the default setting).

In the default +UPSMVER: 15 setting, the module has been configured to be power efficient with PSM, if the module is not granted PSM by the network, it will fall back into PSM without network coordination. Without network coordination the module will enter PSM by detaching from the network as soon as there is inactivity and stay in the sleep mode for 54 minutes. When it wakes from PSM sleep mode, it will need to register with a network once again.

Also, it will periodically enter PSM if it cannot find a network to register on for any +UPSMVER setting.

 PDN context / IP address is not retained with PSM without network coordination.

The following is an example of when PSM is not granted by the network and then the module falls back to PSM without network coordination.

Command	Response	Description
AT+UPSMVER?	+UPSMVER: 15 OK	Read the current +UPSMVER setting (15).
AT+CPSMS=1,,,"00011101","00010101"	OK	Enabling the PSM and optionally set timers. In this example: requesting timers are: <ul style="list-style-type: none"> 00011111: 310 minutes (5 hours 10 minutes) for TAU 0001011: 22 s for active timer
AT+CSCON=1	OK	Enable radio connection status if not enabled.
AT+UPSMR=1	OK	Enable Power Saving Mode indication if not enabled.
AT+CSGT=1,"Greeting Message"	OK	Optionally set a greeting message, which is the text printed when it exists PSM sleep state.
AT+CFUN=15	OK	Reboot to enable the PSM.
	Greeting Message	Greeting message after boot-up.
	+CSCON: 1	RRC connection active.
AT+UPSMR?	+UPSMR: 1	Check power saving mode indication enabled.
AT+CEREG=4	OK	Optionally set the +CEREG mode for registration status notification and format.
AT+CEREG?	+CEREG: 4,1,"2809","29", "9EBB01",7,,,	Let device register The +CEREG read command is one method for an on-demand check of the registration status and PSM assigned settings.
AT+UCPSMS?	+UCPSMS: 0 OK	The +UCPSMS read command response provides PSM assigned settings. In this case, PSM has not been granted by the network..
	+CSCON: 0	RRC goes idle.
	+CSCON: 1	+CSCON indicates RRC is now active to detach from network in this case, where in this example sequence it appears right before +UUPSMR: 1 (next URC event below).
	+UUPSMR: 1	URC indicating device going into PSM low power mode.
		The device enters PSM without network coordination. The key point in this example, is in the above two URC events +CSCON: 1 appear right before +UUPSMR:1. This indicates the network did not grant PSM and therefore the T3324 timer does not apply.
		 This is the only way of checking the PSM has not been granted on SARA-R410M-01B, SARA-R410M-02B-01, SARA-R410M-02B-02, SARA-R410M-02B-03, SARA-R410M-52B,

Command	Response	Description
		SARA-R412M-02B-00, SARA-R412M-02B-01, SARA-R412M-02B-02, SARA-R412M-02B-03, SARA-R4 "63B / 73B / 83B" product variants. Instead +CSCON: 1 is triggered by PSM without network coordination to detach from the network to send the module into PSM sleep. It will remain in PSM for 54 minutes. After it will wake and will have to attach and register to a network again.

If the host application does not desire to use the fallback option to PSM without network coordination, then it can use PSM with network coordination configuration mode only. The guidelines to using it in this configuration are:

- Set the PSM with network coordination mode only (+UPSMVER: 4).
- If the network does not grant the use of PSM, it is still possible to save power with timed periodic graceful shutdown and power-up. To implement this fallback alternative, the host should:
 - Keep track of requested T3324 and T3412 timers to enter and exit PSM, starting them at +CSCON: 0.
 - Check whether PSM has not been granted by the network via the +UCPSMS and +CEREG read commands.
 - To minimize power consumption at the requested T3324 timer expiry gracefully shut down the module to detach itself from the network, releasing the present PDP context.

 From the shutoff state, power up the module again at the requested T3412 timer expiry. On SARA-R410M-02B-01, SARA-R410M-02B-02, SARA-R410M-02B-03, SARA-R412M-02B-00, SARA-R412M-02B-01, SARA-R412M-02B-02, SARA-R412M-02B-03, SARA-R4 "01B" / "52B" / "63B" / "73B" / "83B" product versions, it is not possible to check whether the PSM has not been granted by the network via the +UCPSMS and +CEREG read commands. If the +UCPSMS and +CEREG read commands provide the requested T3324 timer, the only way to know that PSM has not been granted by network is that the module does not enter PSM when the requested T3324 timer expires.

The following is an example of using PSM on SARA-R4 series:

Command	Response	Description
AT+UPSMVER=4	OK	Set PSM mode to PSM with network coordination mode only. It is not recommended to use the default value 15, which has fall back to PSM without network coordination.
AT+CFUN=15	OK	Reboot to enable the PSM with network coordination mode only.
AT+UPSMVER?	+UPSMVER: 4 OK	Confirming set value is 4.
AT+CPSMS=1,,,"00011101","00010101"	OK	Enabling the PSM and optionally set timers. In this example: requesting timers are: <ul style="list-style-type: none"> • 00011111: 310 minutes (5 hours 10 minutes) for TAU • 0001011: 22 s for active timer
AT+CSCON=1	OK	Enable radio connection status if not enabled.
AT+UPSMR=1	OK	Enable Power Saving Mode indication if not enabled.
AT+CSGT=1,"Greeting Message"	OK	Optionally set a greeting message, which the greeting is printed when it exists PSM sleep state.

Command	Response	Description
AT+CFUN=15	OK	Reboot to enable the PSM.
	Greeting Message	Greeting message after boot-up.
	+CSCON: 1	RRC connection active.
AT+UPSMR?	+UPSMR: 1	Check power saving mode indication enabled.
AT+CREG=4	OK	Optionally set +CREG mode for registration status notification and format.
AT+CREG?	+CREG: 4,1,"2809","29", "9EBB01",7,,,, OK	Let device register. The +CREG read command is one method to check on-demand registration status and PSM assigned settings.
AT+UCPSMS?	+UCPSMS: 0 OK	The +UCPSMS read command response provides PSM assigned settings. In this case, the PSM has not been granted by the network.
	+CSCON: 0	RRC goes idle. Now wait for T3324 timer to expire.
		If +CSCON: 0 is observed but +UUPSMR: 1 is not when the requested T3324 timer expires, then it may be PSM is not supported by the network and the host should use graceful shutdown as alternative to minimize power consumption.

18.2.5 PSM indication

There are multiple ways the host application can know when the module is in PSM.

- GPIO “module status indication” – See +UGPIOC AT command
- V_INT monitoring
- RXD monitoring – (if RXD is low for more than 1 character)
- +UPSMR URC – returns ‘1’ when the module is about to enter the PSM.

18.2.6 Host waking module from PSM

When in PSM lower power sleep mode, if the PWR_ON pin is asserted low for a specific time as specified in SARA-R4 series data sheet [1], the module will exit PSM sleep mode.

Once it exits PSM it can follow one of the two options:

1. If there is no data is transferred over the network or AT command activity, it will go back into PSM sleep within ~16-18 s
2. If there is MO triggered network activity, it will wait for local radio connection to release and then for T3324 timer to expire and then go back into PSM sleep mode if no AT command activity.

The following is an example of host waking module from PSM:

Command	Response	Description
		The module is in PSM sleep state. Before T3412 expires, PWR_ON assert event wakes module up from PSM. Assert PWR_ON as guided SARA-R4 series data sheet [1] to wake-up from PSM
	Greeting Message	The device wakes up from PSM and greeting message is printed. In this example, greeting message has been enabled and set.
	+UUPSMR: 0	URC indicating device coming out of PSM sleep mode.

Command	Response	Description
	+UUPSMR: 1	URC indicating device going into PSM sleep mode in ~16-18 s after PWR_ON toggle and no valid activity to prevent it from sleeping in PSM. The device enters PSM.
		Again, PWR_ON assert event wakes module up from PSM.
	Greeting Message	The device wakes-up from PSM and greeting message printed
	+UUPSMR: 0	URC indicating device coming out of PSM sleep mode
AT+USOCR=17	+USOCR: 0 OK	Here is an example of sending data. Setup and send some socket UDP data.
AT+USOST=0, "exampleserver.com", 7, 13, "examplepayload"	+USOST: 0, 5 OK	Send UDP data to destination server.
	+CSCON: 1	RRC connection active.
	+CSCON: 0	RRC idle. Now wait for T3324 timer to expire.
	+UUPSMR: 1	URC indicating device going into PSM low power mode. Device in PSM. Wait for T3412 timer to expire to exit PSM sleep mode.

18.2.7 PSM and roaming

When the module is registered on a roaming network (not a home network), and the default “Automatic network selection” mode is enabled by the +COPS AT command, then the module will periodically search for a HPLMN (Home Public Land Mobile Network). An active HPLMN search delays the entry into the PSM until the search is complete. In other words, if the PSM is enabled and T3324 (active timer) expires, the device may not enter the PSM mode if the HPLMN search is running. It must wait for the search to complete before entering the PSM.

If the device is in roaming condition with “Manual network selection” mode, then there will not be a HPLMN search to delay PSM entry.

18.2.8 PSM and LwM2M

 This section is applicable to SARA-R4 63” / “73”/ ”83” product versions, SARA-R410M-02B-03, SARA-R410M-02B-04, SARA-R412M-02B-03, and SARA-R412M-02B-04.

With PSM enabled, if AT+ULWM2M=1 is applied to stop the LwM2M client, then when the module enters the PSM sleep mode and then later exits the sleep state, the LwM2M client will once again initialize and resume due to its volatile setting. For more details, see SARA-R4 series AT commands manual [2]. If desired to disable the LwM2M client again, a subsequent AT+ULWM2M=1 command is then necessary when the client resumes.

19 Application design for low power

19.1 Static applications

Static applications are characterized by devices that are stationary. Generally, the cell the module connects to will not change throughout the device's life, unless the network operator installs new equipment.

For static applications a single RAT is normally used and Inter-RAT handover is not required.

19.1.1 Battery powered

Battery operated applications should consider all the features provided in 3GPP Release 13, for example PSM, eDRX, release assistance. However, depending on the applications it may be more efficient turning the module off completely between sending uplink messages.

Depending on the application type, specific Release 13 power saving features may or may not be useful. I.e., if the application requires an acknowledgement within a short period of a few seconds, using eDRX may not be required as the acknowledgement is received before the connected mode is released (RRC).

19.1.2 Mains powered

Devices which are mains powered need not utilize the power saving features of 3GPP Release 13, but the application should consider what is best for the network.

The network operator may not allow applications to be continuously connected in connected mode as this takes up resources on the network.

19.2 Mobile applications

Mobile applications need to have other parameters considered which may not be of interest in static applications. For example, the TAU update timer may need to be set to a relatively low period so that the network can track the device's cell location.

20 GNSS

SARA-R4 series modules support reading NMEA strings from the GNSS receiver through AT commands. The GNSS device management can be performed through the cellular module as well.

20.1 Power control

GNSS power management is controlled by the +UGPS AT command. This will control the GNSS device using a configured GPIO. Therefore, the host application must first configure the correct GPIO pin for GNSS supply control.

Issue the `AT+UGPIOC=<gpio_id>,3` command to configure which GPIO pin is controlling the GNSS supply.

21 Testing

21.1 Digital pin testing (+UTEST=10)

Table 2 provides the list of pins that can be tested by means of the AT+UTEST=10 command. The command allows the user to perform some verifications on all the digital pins of the SARA-R4 series modules.

Pin number	Name	Description
6	DSR	UART data set ready
7	RI	UART ring indicator
8	DCD	UART data carrier detect
9	DSR	UART data terminal ready
10	RTS	UART ready to send
11	CTS	UART clear to send
12	TXD	UART data input
13	RXD	UART data output
16	GPIO1	GPIO
19	GPIO6	GPIO
23	GPIO2	GPIO
24	GPIO3	GPIO
25	GPIO4	GPIO
26	SDA	I2C bus data line
27	SCL	I2C bus clock line
34	I2S_WA / SPI_MOSI	I2S word alignment / SPI Master Output Slave Input
35	I2S_TXD / SPI_CS	I2S transmit data / SPI Chip Select
36	I2S_CLK / SPI_CLK	I2S clock / SPI clock
37	I2S_RXD / SPI_MISO	I2S receive data / SPI Master Input Slave Output
42	GPIO5	SIM detection
44	SDIO_D2	SDIO serial data [2]
45	SDIO_CLK	SDIO serial clock
46	SDIO_CMD	SDIO command
47	SDIO_D0	SDIO serial data [0]
48	SDIO_D3	SDIO serial data [3]
49	SDIO_D1	SDIO serial data [1]

Table 2: SARA-R4 pins for +UTEST=10 testing

Below is an example of configuring GPIO 1 as output and set to high.

Command	Response	Description
		Configure the formatting of the error result code by means of +CMEE AT command.
AT+COPS=2	OK	Deregister the module from the network.
AT+UTEST=1	OK	The module enters the test mode.
AT+UTEST=10,1	(pin description returned) OK	Gets the pin information.

21.2 Testing with network simulators

When testing with network simulators, such as a CMW500 from Rohde & Schwarz as one example among many, the simulator may not be configured to release the local RRC connection when there is an idle period.

 The +UMACQOSTMR AT command is supported by SARA-R4 “02” product versions except for SARA-R410M-02B-00, SARA-R410M-02B-01, SARA-R410M-02B-02, SARA-R412M-02B-00, and SARA-R412M-02B-01.

On products / firmware that feature the +UMACQOSTMR AT command timer, this timer may need to be disabled to allow certain measurements. RF sensitivity measurements, for example, expect the local RRC connection to remain in the connected state. If this MAC QoS timer is not disabled, then after the timer expires, it will release the RRC connection with the simulator and may interrupt the measurement.

Here is an example of checking for the MAC QoS timer value and setting it

Command	Response	Description
AT+UMACQOSTMR?	+UMACQOSTMR: 35, -1 OK	Check if MAC QoS timer is enabled by reading it. In this example, it is enabled for LTE Cat. M1 with 35 s timer. It is disabled for NB-IoT.
AT+UMACQOSTMR=0	OK	Disabled MAC QoS timer for LTE Cat. M1 with 0 value set.
AT+CFUN=15	OK	Reset the device for new value to disable MAC QoS timer.
AT+UMACQOSTMR?	+UMACQOSTMR: -1, -1 OK	Confirm MAC QoS timer is disabled, which in this example it is reflected as disabled with “-1” value for both LTE Cat. M1 and NB-IoT.

Another factor to consider with using a test simulator is the need for using a dedicated test SIM. For more details, see section [25.1](#).

22 Debugging

22.1 Logging port

SARA-R4 series modules assign the USB interface for logging capabilities.

 For full debugging of the module, customers must use a dedicated logging application. Customers need to request for this debug application, which is licensed. This debug tool is not free to use.

 The standard u-blox m-center tool is able to capture a modem log that is limited to certain message traces. A limitation of the log output is that it lacks over-the-air traces, which are needed to debug connectivity to the cellular network. A custom m-center version is capable of capturing the over-the-air traces. m-center includes instructions on how to capture a log through its built-in help menu. If needed, contact u-blox support for guidance about taking an m-center trace or for more details on the custom m-center.

- The USB interface for logging will also work in parallel to the AT commands port.
- It is strongly recommended to add USB test points for later debugging.

For application using the UART interface to issue AT commands, the module must boot up without the USB interface connected to a host device. This allows the UART interface to establish AT connectivity with the host MCU. After the UART communication is established the USB interface can be connected for logging.

If the full attachment / registration procedure is desired in the logs or any commands that quickly follow registration, then the host app shall set the device to minimal functionality with `AT+CFUN=0`, and then issue `AT+CFUN=1` when ready to log.

Before capturing any logs, ensure the device has the logging bitmask correctly set to enable full logging output with `+ULOG` AT command.

Command	Response	Description
AT+ULOG?	+ULOG: 0, ("LTE", 0x00), ("DS", 0x00), ("LEG", 0x00) OK	Check logging bitmask. 0x00 values indicate logging output disabled.
AT+ULOG=2	OK	Set logging bitmasks for full logging output.
AT+ULOG?	+ULOG: 0, ("LTE", 0x1F), ("DS", 0x1F), ("LEG", 0x1F) OK	Check logging bitmask. 0x1F values indicate logging output enabled. The device is ready to take logs, but settings are not persistent.
AT+ULOG=1	OK	Make persistent the present logging bitmask value (optional step).
AT+CFUN=15	OK	Reset the device.
AT+ULOG?	+ULOG: 0, ("LTE", 0x1F), ("DS", 0x1F), ("LEG", 0x1F) OK	Check the logging bitmask after module reset. 0x1F values indicate logging output enabled as expected because AT+ULOG=2, then followed by AT+ULOG=1 option applied successfully. The device is ready for logging.

23 Migration

23.1 SARA-G3

23.1.1 PDP activation

The PDP context activation is the same on SARA-R412M in 2G network (+URAT: 9).

23.1.2 +UPSDA

SARA-R4 series modules will automatically activate sockets on <cid> =1 (PDP context id).

24 SMS

24.1 SMS preferred message storage

The factory-programmed value for SARA-R4 series is "ME" for the three memory parameters <mem1>, <mem2>, and <mem3>. The setting can be set or read by +CPMS. However, on SARA-R4 modules, the memory storage must be all the same type and cannot be mixed.

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

Command	Response	Description
AT+CPMS="ME", "ME", "ME"	+CPMS: 0,23,0,23,0,23 OK	Set all three memory storage parameters to "ME" memory storage.
AT+CPMS?	+CPMS: "ME",0,23,"ME",0,23,"ME",0,23 OK	Read the storage setting back.

For more details on the +CPMS AT command, see SARA-R4 series AT commands manual [\[2\]](#).

25 SIM

25.1 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, configure a device(s) with a SIM card holder for physical removable SIM for such engineering or pre-production activities.

26 WWAN adapter

The Qualcomm WWAN adapter is not supported by u-blox.

26.1 Disabling Qualcomm WWAN adapter

When connecting the SARA-R4 module to a Windows based PC, ensure the WWAN adapter is disabled. By default, it will be enabled and therefore it requires a “right click” in Windows over this adapter to bring up the menu to disable it.

For Microsoft Windows 10, the operating system is set to connect to the WWAN adapter automatically. If connected, it routes data traffic from the PC to the cellular network via SARA-R4.

Disable this adapter to log and perform device data calls.

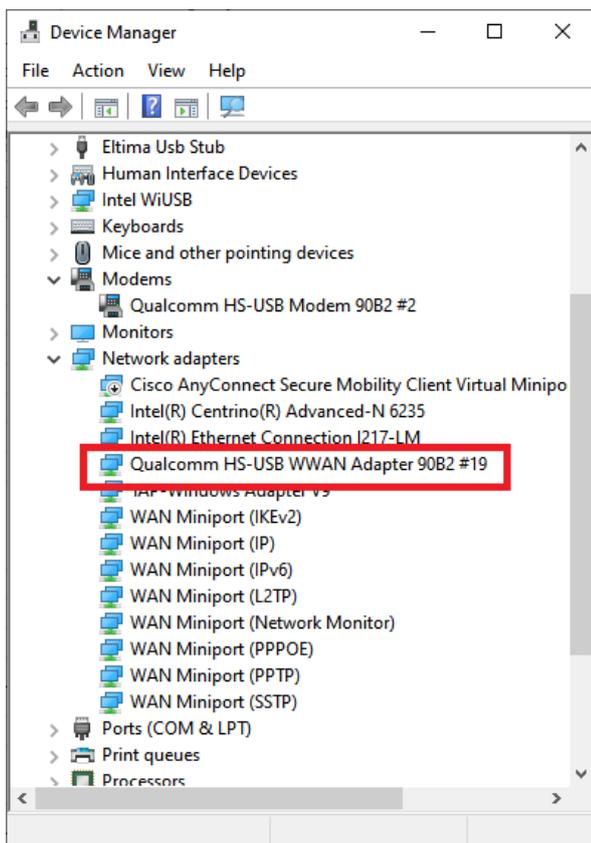


Figure 3: Windows Device Manager: Qualcomm WWAN port that needs to be disabled

27 EFS Backup & Restore

 EFS / Backup & Restore feature is not supported on SARA-R4 “52” / “63” / “73” / “83” product versions, SARA-R410M-02B-00, SARA-R410M-02B-01, SARA-R410M-02B-02, SARA-R412M-02B-00, SARA-R412M-02B-01, and SARA-R412M-02B-02.

Due to the nature of Flash memory, the Embedded File System (EFS) may incur memory corruption if the safe & graceful shutdown procedure outline in the SARA-R4 series system integration manual [3] is not followed. It is possible that memory corruption may result in the device being inoperable or impact specific device data info.

For fatal memory corruption, the EFS Backup & Restore 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 backup to supersede the previous backup copy. If 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 & graceful shutdown procedure outline in the SARA-R4 series system integration manual [3]. Backup & Restore feature is intended only as an addition backup mechanism, if on the potential rare occasion, the host application shutdown is not conforming to the graceful power down guidelines.

27.1 Description

There are two parts to the EFS (Electronic File System) backup & restore feature for SARA R410M and SARA-R412M module product types with FW versions that support this feature.

The backup 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. This includes NV settings, current MNO profile, user files and certificates.

There is a special case where the backup counter goes to zero from a non-zero value. For more details, see section 27.1.1.

The restore feature allows the modules to automatically recover from a fatal file system corruption, where the module cannot fully boot up. The module uses this function when it detects such a corruption from a previous improper shutdown at the next module boot-up. For deployed field devices, if the corruption is non-fatal and the module can boot up, the host can manually trigger a restore.

There are three known types of non-fatal corruption:

- Loss of IMEI
- MNO profiles lost or duplicated
- Device goes into the non-signaling mode (for more details, see the +UTEST=10 AT command in the SARA-R4 series AT commands manual [2])

 Only in one of the above conditions should a restore be host triggered.

27.1.1 EFS backup

The EFS backup can be initiated with the +UBKUPDATA AT command and will automatically trigger a module reset upon receiving the command. After the backup process has finished, the device will perform another reset and store status information that can be queried with an AT command. After the device is finished with the backup, no further action is required.

The host can issue backup on an infrequent & rare basis that justifies for such a 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. One likely point of needing a backup is after the host application factory initial "production", which may include configuration of the module to a specific use case requirement. The backup command can also be used to query how long it has been since the last backup.

 It is recommended to enable greeting text messages via the +CGST AT command after first power-up at the host application factory. It is also recommended to trigger a manual backup after the device has been fully configured at production. This way if the restore event should occur in the field, the greeting text will help to indicate that the AT interface is available and the module is ready to run with the production configuration.

Additionally, there is a special case when host can issue a backup: backup counter for number of backups goes to zero from a non-zero value. This counter can be read and monitored with the +UBKUPDATA AT command.

 Modules with factory-programmed configuration come with a backup copy and therefore the backup counter would be 1, which should be verified in host device production. If this counter should later go to 0, the host should trigger a backup and then after completed, verify the counter has a value of 1.

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

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

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

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

To detect when the backup function is complete, and the AT interface is available here are following options:

- Wait for **+UUBKUPDATA** URC
 - Example for backup successful: +UUBKUPDATA: 1,1
- Loop AT until the OK final result code is issued
 - Example: send AT every one second until the OK final result code is got
- Enable and monitor GPIO for "Module status indication" via +UGPIOC AT command
- Enable and monitor greeting message +CSGT

27.1.2 EFS restore

When an automatic restore is triggered, the device will immediately reset (this may interrupt any currently running processes) and reset/restore the file system. The device will then reset again, and store status information that can be queried with an AT command. After the device is finished with the restore, 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 next 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 typical. 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 URC notification.

Example: the **+UUBKUPDATA: 2,1** URC indicates restore has taken place and is successful.

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

- Loss of IMEI, which can be checked and detected with the +CGSN or ATI command, where:
 - The +CGSN AT command would return the "+CME ERROR: memory failure" error result code
 - The ATI command for Identification Information would return a blank IMEI in the response
- MNO profiles lost or duplicated, which can be checked and detected by the +UMNOPROF AT command
- The device goes into the non-signaling mode and is unable to exit with AT+UTEST=0 and the +CFUN AT command 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, and the host should verify that the restore operation corrects the issue if executed.

Example on using the +CGSN and ATI command to detect lost IMEI

Command	Response	Description
AT+CGSN	+CME ERROR: memory failure	Error response indicates lost IMEI using +CGSN command. The error response format differs between each +CMEE setting. The example shown here is for +CMEE: 2.
ATI	Manufacturer: u-blox Model: SARA-R410M-02B Revision: L0.0.00.00.05.12 [Jan 01 2021 12:00:00] IMEI: OK	Blank IMEI indicates lost IMEI using ATI command

With the possibility of a restore event, to detect when the module boot-up is complete and 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 GPIO for “Module status indication” functionality via the +UGPIOC AT command
- Enable and monitor the greeting message via the +CGST AT command
- Both the module status indication and greeting message option would require to be enabled and then saved into the EFS backup copy. If a restore should ever be triggered, then the EFS backup copy would be restored with the feature enabled.

27.1.3 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 the host needs to perform a backup with +UBKUPDATA AT command before testing or relying on this the Restore feature.

27.1.4 Automatic EFS backup performed after EasyFlash

After a successful firmware flash using EasyFlash as indicated by the green graphic user interface progress bar and “SUCCESS!” status message, the module is armed to trigger a backup upon the first boot. Do allow the boot-up and backup time for the backup process, as guided by in section 27.1.1. If the device is left powered on after the EasyFlash process is complete it will automatically boot and perform the backup.

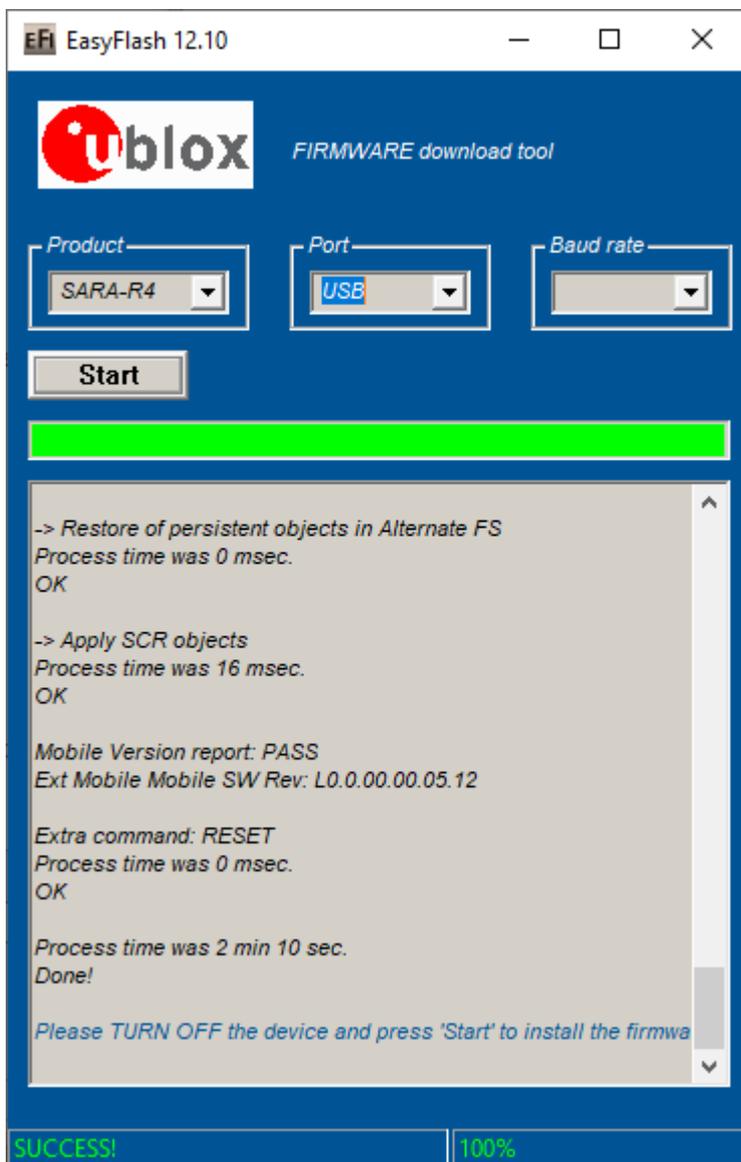


Figure 4 Flashing module is completed. Module will boot-up after success and perform first Backup.

After the first backup is performed automatically post flashing with EasyFlash, confirm the backup copy.

Command	Response	Description
AT+UBKUPDATA?	+UBKUPDATA: 0,0,1,0,0,0,"" OK	Backup copy confirmed as indicated by the "1" for one backup performed.

27.1.5 EasyFlash and SMS storage

If a FW build with the Backup & Restore feature is being flashed onto a module via EasyFlash, after a successful flash when the device boots up, then the host is required to set preferred SMS message storage with +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.

Appendix

A LTE Cat M1 vs NB1

SARA-R4 series modules can communicate using the 3GPP LTE Cat M1 and NB1 technologies. They both have features based on the 3GPP Release 13 specification.

	Rel. 13 Cat M1	Rel. 13 NB-IoT
Deployment	In-band LTE	In-band, guard band LTE, and standalone
Coverage	155.7 dB	164 dB
Downlink	OFDMA, 15 kHz tone spacing, Turbo code, 16 QAM, 1 Rx	OFDMA, 15 kHz tone spacing, TBCC, 1 Rx
Uplink	SC-FDMA 15 kHz tone spacing, Turbo code, 16QAM	Single tone, 15 kHz and 3.75 kHz spacing SC-FDMA, 15 kHz tone spacing Turbo code
Bandwidth	1.08 MHz (6 resource blocks)	180 kHz (1 resource block)
Duplexing	FD, HD (Type-B), FDD/TDD	HD only (Type-B), FDD-only (TDD for future releases)
Peak rate (UL/DL)	1 Mb/s DL and UL	DL – ~32 kb/s (in-band), 34 kb/s (standalone) UL – ~66 kb/s multitone, ~17 kb/s single tone
Power saving	PSM, eDRX, DRX	PSM, eDRX, DRX
Power class	Class 3 (23 dBm)	Class 3 (23 dBm)
Core network	Same as LTE	Simplified core network(optional), small data enhancements (data over NAS or user plane with security context in RAN) (additional non-IP data support)

B Glossary

Abbreviation	Definition
3GPP	3rd Generation Partnership Project
APN	Access Point Name
AT	AT Command Interpreter Software Subsystem, or attention
BIP	Bearer Independent Protocol
CHAP	Challenge Handshake Authentication Protocol
DCE	Data Communication Equipment
DL	Downlink
DLCI	Data Link Connection Identifier
DRX	Discontinuous Reception
DTE	Data Terminal Equipment
DUN	Dial-up Networking
eDRX	extended Discontinuous Reception
EMM	EPS Mobility Management
EPS	Evolved Packet System
FDD	Frequency Division Duplex
FOTA	Firmware Over The Air
FTP	File Transfer Protocol
GNSS	Global Navigation Satellite System
GPIO	General Purpose Input Output
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSMA	GSM Association
HTTP	HyperText Transfer Protocol
ICCID	Integrated Circuit Card ID
IIN	Issuer Identifier Number
IMEI	International Mobile Equipment Identity
IP	Internet Protocol
L1	Layer 1
LCP	Link Control Protocol
LPWAN	Low-Power Wide-Area Network
LTE	Long Term Evolution
M2M	Machine to Machine
MCU	Multipoint Communication Unit
MDN	Message Disposition Notification
ME	Mobile Equipment
MNO	Mobile Network Operator
MQTT	Message Queueing Telemetry Transport
MSC	Modem Status Command
MT	Mobile Terminated
MVNO	Mobile Virtual Network Operator
NAS	None Access Stratum
NB-IoT	Narrow Band IoT
NMEA	National Marine Electronics Association

Abbreviation	Definition
NVM	Non Volatile Memory
NW	Network
OFDMA	Orthogonal Frequency-Division Multiple Access
PAP	Personal Authentication Protocol
PDP	Parallel Data Protocol
PLMN	Public Land Mobile Network
PPP	Point-to-Point Protocol
PS	Protocol Stack
PSM	Power Save Mode
RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
RRC	Radio Resource Control
RRM	Radio Resource Management
RTC	Real Time Clock
RX	Reception
SC-FDMA	Single-carrier FDMA
SIM	Subscriber Identification Module
TAU	Tracking Area Update
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TX	Transmission
UART	Universal Asynchronous Receiver-Transmitter
UDP	User Datagram Protocol
uFOTA	u-blox FOTA
UL	Uplink
URC	Unsolicited Result Code
USB	Universal Serial Bus

Table 3: Explanation of the abbreviations and terms used

C SIM issuer identification number database

Table 4, Table 5, and Table 6 provide the list of SIM issuer identification number (IIN) database. These databases are used when either auto select MNO profile 1 is used or with the IIN detection feature found on SARA-R410M-63B-00.

The IIN database presented in the tables are for what comes from the factory loaded by the carrier profiles loaded for a given firmware.

If the profile is not listed, then there are no IIN values related to that profile as in example MNO profile 100 (Standard Europe).

	NTTDoCoMo	SKT	SoftBank	Telstra
SARA-R410M-63B-00	898110 898103	898205 898211	898100 898120	
SARA-R410M-73B-00			898165 898170 898171	
SARA-R410M-83B-00				896101

Table 4: SARA-R410 “63” / “73” / “83” SIM INN values stored on device database used for MNO profile selection

	AT&T	China Telecom	Deutsche Telekom	Sprint
SARA-R410M-02-00	8901410 8901030 8901150 8901170 8901560 8901680 890138	898603 898606 898611 8985302 8985307		
SARA-R410M-52-00	8901410 8901030 8901150 8901170 8901560 8901680 890138			
SARA-R412M-02-00			8988228	
SARA-R410M-02-01	8901410 8901030	898603 898606	8988228	896101
SARA-R410M-02-02	8901150 8901170 8901560 8901680 890138	898611 8985302 8985307		
SARA-R410M-52-01	8901410 8901030			
SARA-R410M-52-02	8901150 8901170 8901560 8901680 890138			
SARA-R412M-02-01	8901410 8901030		8988228	
SARA-R412M-02-02	8901150 8901170 8901560 8901680 890138 8901253 8901288 8901284			

Table 5: SARA-R410M and SARA-R412M “02” / “52” product versions SIM IIN values stored on device database used for MNO profile selection (part I)

	Telstra	T-Mobile US	Vodafone	Verizon
SARA-R410M-02-00			894410 8988239 894410	891480 891004 891005 891012 891650 891433 891444 891483 891486 891487 891489 891808
SARA-R410M-52-00				891480 891004 891005 891012

	Telstra	T-Mobile US	Vodafone	Verizon
SARA-R410M-52-01				891480 891004
SARA-R410M-52-02				891005 891012
SARA-R412M-02-00	891223 890124	8949024 8944302 8901026 8901160 8901260 8901490	894410 8988239 894410	
SARA-R410M-02-01				891480 891004
SARA-R410M-02-02				891005 891012
SARA-R410M-02-03				891650 891433 891444 891483 891486 891487 891489 891808
SARA-R412M-02-01		8949024 8944302	894410 8988239	
SARA-R412M-02-02		8901026 8901160	8935502 8942031	
SARA-R410M-02-03		8901260 8901490 8901210 8901230 8901240 8901270 8901310 8901580	894920 893005 8935402 893910 8935601 893144 8935101 894001 893456	

Table 6: SARA-R410M and SARA-R412M “02 / 52” product versions SIM IIN values stored on device database used for MNO profile selection (part II)

Related documentation

- [1] u-blox SARA-R4 series data sheet, [UBX-16024152](#)
- [2] u-blox SARA-R4 series AT commands manual, [UBX-17003787](#)
- [3] u-blox SARA-R4 series system integration manual, [UBX-16029218](#)
- [4] u-blox SARA-R4 series Firmware update application note, [UBX-17049154](#)
- [5] u-blox SARA-R5 / SARA-R4 series GNSS implementation application note, [UBX-20012413](#)
- [6] u-blox Mux implementation in cellular modules application note, [UBX-13001887](#)
- [7] u-blox LwM2M objects and commands, [UBX-18068860](#)
- [8] u-blox EVK-R4 user guide, [UBX-16029216](#)
- [9] u-blox LTE attachment & transport planes presentation, [UBX-19006672](#)
- [10] u-blox IoT Security-as-a-Service overview,
<https://developer.thingsstream.io/guides/security-services>
- [11] 3GPP TS 36.321 - Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification
- [12] 3GPP TS 36.101 - LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception
- [13] 3GPP TS 24.008 - Annex G (informative): 3GPP specific cause values for mobility management
- [14] 3GPP TS 24.301 - Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3
- [15] 3GPP TS 27.010 - Terminal Equipment to Mobile Station (TE-MS) multiplexer protocol
- [16] RFC 6347 - Datagram transport layer security (DTLS)
- [17] RFC 793 - Transmission control protocol (TCP) protocol specification

 For regular updates to u-blox documentation and to receive product change notifications, register on our homepage (www.u-blox.com).

Revision history

Revision	Date	Name	Status / Comments
R01	25-Oct-2018	pwar / clee	Initial release
R02	07-Dec-2018	pwar / clee	Review release
R03	04-Feb-2019	pwar / clee	General release
R04	08-Feb-2019	pafe	Extended document applicability to SARA-N4 series
R05	19-Jun-2019	pwar	Minor updates
R06	30-Sep-2019	skri / clee	Added SMS
R07	27-Jan-2020	clee	Extended document applicability to SARA-R410M "63" / "73" product versions
R08	12-Jun-2020	clee	Extended document applicability to SARA-R410M-83B product version Added disabling WWAN adapter
R09	03-Sep-2020	clee	Minor updates
R10	10-Dec-2020	clee	Minor updates
R11	03-Mar-2021	clee	Added EFS backup & restore
R12	17-Sep-2021	clee	Minor updates
R13	08-Jul-2022	clee	Added guidance of 1. configuration for T-Mobile US network, 2. multi IMSI MVNO SIMs, 3. performing a restore if Backup/Restore counters go to zero. Updated section: PSM Modes

Contact

For further support and contact information, visit us at www.u-blox.com/support.