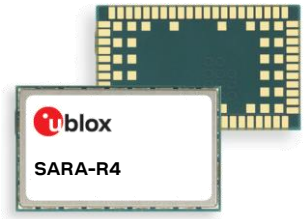
SARA-R42

Application development guide

Application note



Abstract

This document provides detailed technology architecture and examples of how to use AT commands with u-blox SARA-R422 / SARA-R422S / SARA-R422M8S / SARA-R422M10S modules.

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1 Introduction

This document provides guidance for developing applications that interface with the u-blox SARA-R422 / SARA-R422S / SARA-R422M8S / SARA-R422M10S modules, including AT command sequences examples for specific use cases. Throughout the document, “SARA-R42” represents any of these modules.

This should be the first document to read when working on an application integrating a SARA-R42 module.

Table 1 shows a summary of the documentation available for SARA-R42.

	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).
	Production and validation test app note	Guidelines of OEM production test and validation test. Contact tech support for this document
	Internet applications development guide app note [5]	Any applications relying on the IP stack (sockets, MQTT, MQTT-SN, HTTP, FTP, CoAP, SSL/TLS).
	IoT Security-as-a-Service overview [6]	IoT-as-a-Service features (local encryption, E2E encryption, E2E symmetric KMS, Chip-to-Chip, Zero Touch Provisioning).
	GNSS implementation app note [7]	GNSS interface and aiding clients. Techniques for hybrid positioning and timing indication.
	LwM2M application note [9]	Details about the LwM2M options to achieve a few mandatory objects, extensible object and Firmware Over The Air update (uFOTA).
	AT command connect to AWS IoT core [10]	Examples of how to use AT commands to interact with the AWS IoT service.
	Mux implementation app note [8]	Usage of multiplexer with cellular modules.
	EVK-R4 user guide [11]	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-R42 documentation overview

See SARA-R4 series AT commands manual [2] for detailed AT command descriptions.

The following symbols highlight important information:

☞ 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 Cellular technology overview

SARA-R42 modules support LTE Cat M1 and NB-IoT as LPWAN technologies, with 2G RAT fallback, making them ideal for a wide range of applications including:

- Automotive and 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 enables the connection to IoT and M2M devices with medium data rate requirements. It increases battery lifespans thanks to enhanced power saving mode and extended in-building range (up to 15 dBm more than LTE, thanks to the repetitions of transmissions provided in the Coverage Enhancement modes), as compared to standard cellular technologies such as 2G, 3G, or LTE Cat 1.

LTE Cat M1 is defined by the 3GPP Release 13 and is a LPWA technology operating in the licensed spectrum. Operating in half duplex mode with typical speeds of 375 kbit/s, which can reach 1 Mbit/s on some networks thanks to protocol stack enhancements, 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 (uFOTA, with access to MNOs and u-blox servers via the LwM2M protocol) 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.

The LTE Cat M1 standard specifies Connected Mode Mobility, which the module supports through inter-frequency and intra-frequency handover capability, resulting in higher reliability of transmissions, particularly important in non-static usage.

2.2 NB-IoT

Narrowband IoT (NB-IoT Internet of Things) is a Low Power Wide Area (LPWA) technology standardized by 3GPP release 13 as a specialization of the LTE standard, operating with 200 kHz bandwidth which allows it to work virtually anywhere. Since it operates in licensed spectrum, it is secure and reliable, providing guaranteed quality of service.

NB-IoT is optimized for applications that need to communicate small amounts of data over long periods of time. Like Cat M1, it offers very low power consumption and excellent extended coverage in buildings and underground. 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.

SARA-R4 series modules support both CP (Control Plane) and UP (User Plane) Cellular IoT EPS optimizations, Cat-NB2 (3GPP Release 14 upgraded version of the NB-IoT standard, which increases the maximum bit rate from ca 30-60 kbit/s to up to 120-160 kbit/s), NAS and AS (Access Stratum) RAI (Release Assistance Indicator) for faster release of the RRC connection at the end of the data transactions.

2.3 GSM/EGPRS

To assure global coverage, the module supports also 2G legacy RAT. It supports EGPRS class 33 with a downlink maximum speed of ~ 290 kbit/s (the peak bit rate depends on the quality of the radio link).

Being a data-only device, in 2G RAT, besides performing GPRS attach, the module also registers for CS (Circuit Switched) services to enable the GSM SMS service. This is a major difference compared to NB-IoT RAT, where often the SMS service is granted even if the LTE attach is accepted for EPS services only, thanks to the "SMS only" option negotiated during the LTE attach. Another major difference is that the host application needs to activate a PDP context to get an IP address and to use the module's IP based applications.

2.4 Low power profile features

When integrating SARA-R4 series modules in a low power consumption device, it is recommended to enable the power saving mode via `+UPSV` AT command. Depending on the configuration of the serial line used, different `+UPSV` modes can be selected (see the SARA-R4 series system integration manual [3] and the SARA-R4 series AT commands manual [2]).

To benefit from the enhancement of the LPWA standards, the power saving mode (PSM) can be enabled too. In normal service in LTE Cat M1 and NB-IoT, during inactive phases the PSM feature forces the module to enter a low power mode state, where the module is totally deactivated. The state is exited either if the host application needs to trigger data or AT commands, or when the device shall perform the periodic registration to the LTE network, which in PSM is done less frequently than in normal, non-PSM operational mode (for example, after a few hours). Overall, this behavior is more convenient with respect to usage of on-demand radio switch off/on via `AT+CFUN=0/1` but has the disadvantage of long-lasting non-reachability periods while the device is deactivated. Similarly, host applications using mobile-terminated user data (for example, SMS) can rely on eDRX (extended DRX) to keep the power consumption at an optimal level while retaining reachability.

SARA-R4 series modules assure enhanced coverage thanks to the support of CE (Coverage Enhancement) modes A and B; this benefit is balanced by longer transmission duration due to the several repetitions, which the host application can mitigate by using a reduced transmission duty cycle for optimal tradeoff.

3 Application design and development

When designing a host application interfacing with a u-blox cellular module, consider the points 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 of the product.

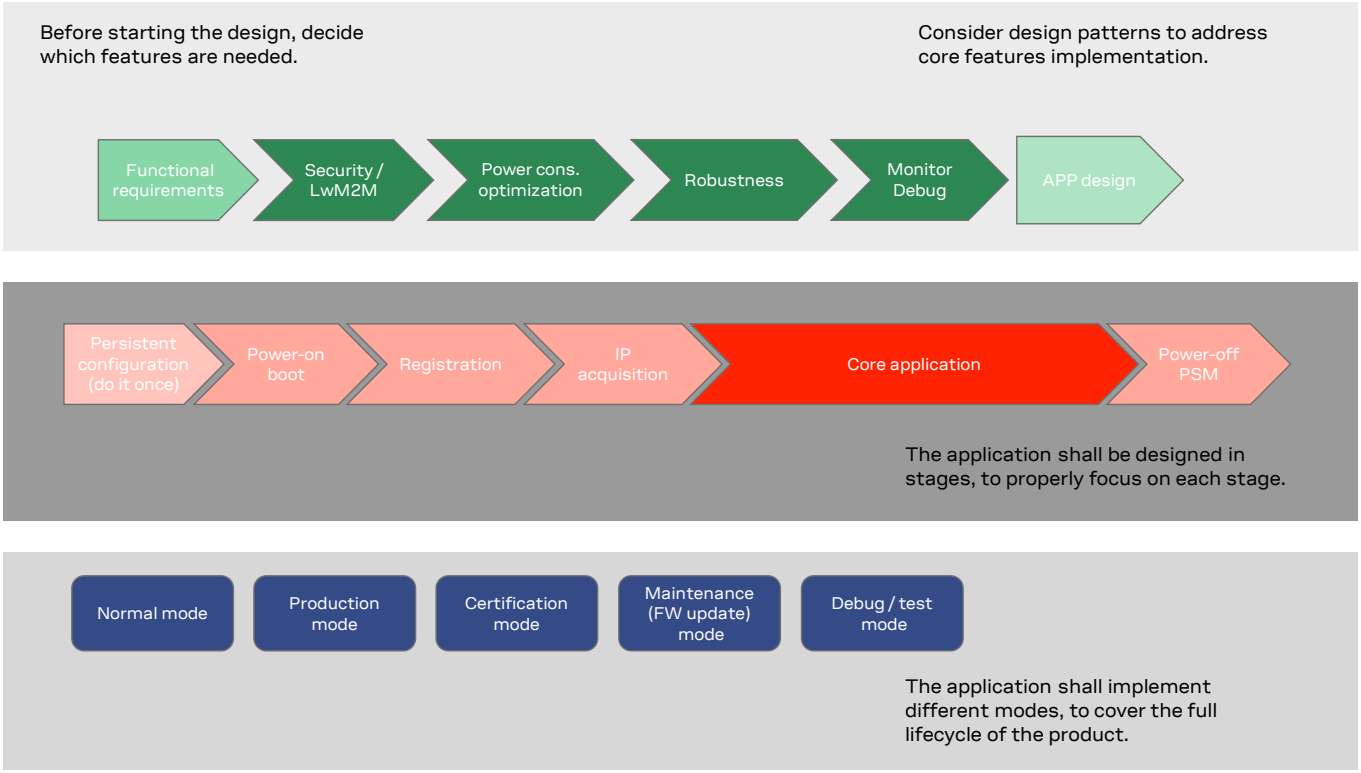

Figure 1: Application design

3.1 Initial design decisions

Features not be used during the application lifetime should be disabled or properly configured to minimize their impact on the overall performance. Carefully decide at design stage, as later changes can cause much effort to adapt and validate the application.

These decisions concern:

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

In detail the LwM2M client is:

- enabled by default in the SARA-R42 "00B" product versions;
- disabled by default in the SARA-R42 "01B" product versions apart from the Verizon MNO profile, i.e. "`AT+UMNOPROF=3`".

An LwM2M client is necessary so that MNOs can contact the device and retrieve diagnostic information. It also enables automatic periodic checking of FOTA update availability, 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 it can implement alternative or additional methods to implement FW updates when triggered 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 8.

The MNO profile 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. For more details, see section 6 and the SARA-R4 series data sheet [1].

The module is debuggable via test endpoints, access to the USB interface, and in general the application log of AT command history, including diagnostic information sent by the module. Monitoring the module status is required to implement recovery procedures via HW or SW, as described in section 9.

☞ It is suggested to disable the LwM2M client, especially in the scenarios in which the related features are not explicitly required by the MNO and not needed by the user.

3.2 Application stages

3.2.1 Persistent configurations

Some module settings are persistent, that is, they are stored in the module's non-volatile memory (NVM). Among these are the MNO profile, APN for Internet connectivity, and active LTE bands.

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

☞ See the SARA-R4 FW update application note [4] for persistence of settings after a FW update. If settings are not retained, they shall be reapplied, see section 3.2.2.

3.2.2 Power on/boot/PSM exit

In general, at each boot, the application should verify the configurations. If verification failed, the persistent configurations can be reapplied.

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

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

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

3.2.3 System time

The application shall configure module's time to keep this information updated, because of its importance and its consequences on the overall system behavior.

There are several ways to set the current date and time on cellular module:

- if an updated time is available at host side, the application could set the module time through the +CCLK AT command at booting time;
- automatic update of local time through the Network Identity and Time Zone (NITZ) feature, if supported by the selected MNO. In particular this action is automatically performed and it is related to the +CTZU AT command settings. When the time zone update is enabled and the MNO supports the NITZ feature in its procedures (e.g. network attach), the module time is automatically updated and its value could be checked through the +CCLK AT command; be aware that NITZ information are sent only at first registration, so it is recommended to perform a detach/attach cycle after enabling the automatic time zone update via NITZ.
- if a GNSS receiver is available and accessible in the system architecture, the application can retrieve the UTC time from GNSS through the +UGTMR AT command, the +CCLK value is then automatically updated; be aware that time zone must be manually set
- the application could implement a specific functionality (e.g. based on sockets) in order to retrieve time information from suitable time servers and then properly set the module time referring the +CCLK AT command.

☞ SARA-R42 “00B” product version: +CTZU factory-programmed value is 0, i.e. automatic time zone via NITZ as disabled.

☞ SARA-R42 “01B” product version: +CTZU factory-programmed value is 1, i.e. automatic time zone via NITZ as enabled.

3.2.4 Network registration

For details about the network registration stage, see section 7.

3.2.5 IP acquisition

For some details and guidelines on this topic, see the Internet applications development guide application note [5].

3.2.6 Core application

For details and guidelines on this topic, see the Internet applications development guide application note [5] and SARA-R4 series AT command manual [2]. The application shall handle AT commands, responses and unsolicited indications as suggested in section 4. For diagnostic purposes, the application should rely on status AT commands, see section 9.1. For robustness purposes, the application should implement embedded watchdog procedures, see section 9.2.

3.2.7 Power-off

The application might need to switch off the module. Both normal and emergency shutdown are described in the SARA-R4 series system integration manual [3].

3.3 Application modes

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

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 strategies as described in section 9.

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 can be done with configuration files, that can be side-loaded to the file system. In extreme cases, it may be necessary to provide an AT interface passthrough to allow access to diagnostic AT commands.

If the cellular communication is tested against a network simulator, use a suitable test SIM card (usually provided by the network simulator manufacturer). If a test SIM card is not available, make sure to disable authentication and integrity checks on the tester side and on the module (by using the `AT+UDCONF=81,0` command, see SARA-R4 series AT commands manual [2]).

3.3.2 Production testing

This mode is to be used during the production tests of the end device. In this scenario the main application is usually inactive, and AT commands can be used to properly configure the module and use its end user testing features (see section **Error! Reference source not found.**).

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

3.3.4 Firmware update mode

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

4 AT commands response parser

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

Basic guidelines:

- When entering AT commands, spaces are ignored.
- The DTE shall handle the case of unexpected spaces or line endings, i.e. the <CR><LF> characters.
- As suggested in the SARA-R4 series AT commands manual [2], always wait for at least 20 ms following a final result code or a URC reception before issuing a new AT command.
- When the module has finished processing an AT command, it will output a final result code (either OK or ERROR) indicating that it is ready to accept a new AT command. The information text responses are issued before the final result code. Change +CMEE setting to numeric or verbose value (i.e., AT+CMEE=1 or AT+CMEE=2).
- Asynchronous commands, e.g., +UMQTTC, return an immediate final result code and final result via URC.
- Some AT commands return an intermediate result code (IRC) during command execution.

☞ Due to interface restrictions, when using multiple AT command interfaces, the parser should consider that in SARA-R42 series it is not possible to have parallel activity on two or more AT terminals. This behavior can be detected in the following configurations:

  - double UART availability, i.e. +USIO:1;
  - virtual channels set through multiplexer (MUX).

  The only allowed parallel activity is present when it is defined a system architecture with a PPP dial-up on one port and AT commands on the other one.

4.1 Operational modes of the AT interface

When implementing the AT parser, it is important to consider that the communication port, whether the main UART or a MUX virtual port, enters different operational modes while processing AT commands.

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

Figure 2 depicts the various modes in which the module can operate and shows the actions that cause transitions between the different modes. The transitions triggered by DTR line changes are configurable with the AT&D command, see SARA-R4 series AT commands manual [2].

For more details about the AT command interface settings, see the AT command settings section in the SARA-R4 series AT commands manual [2].

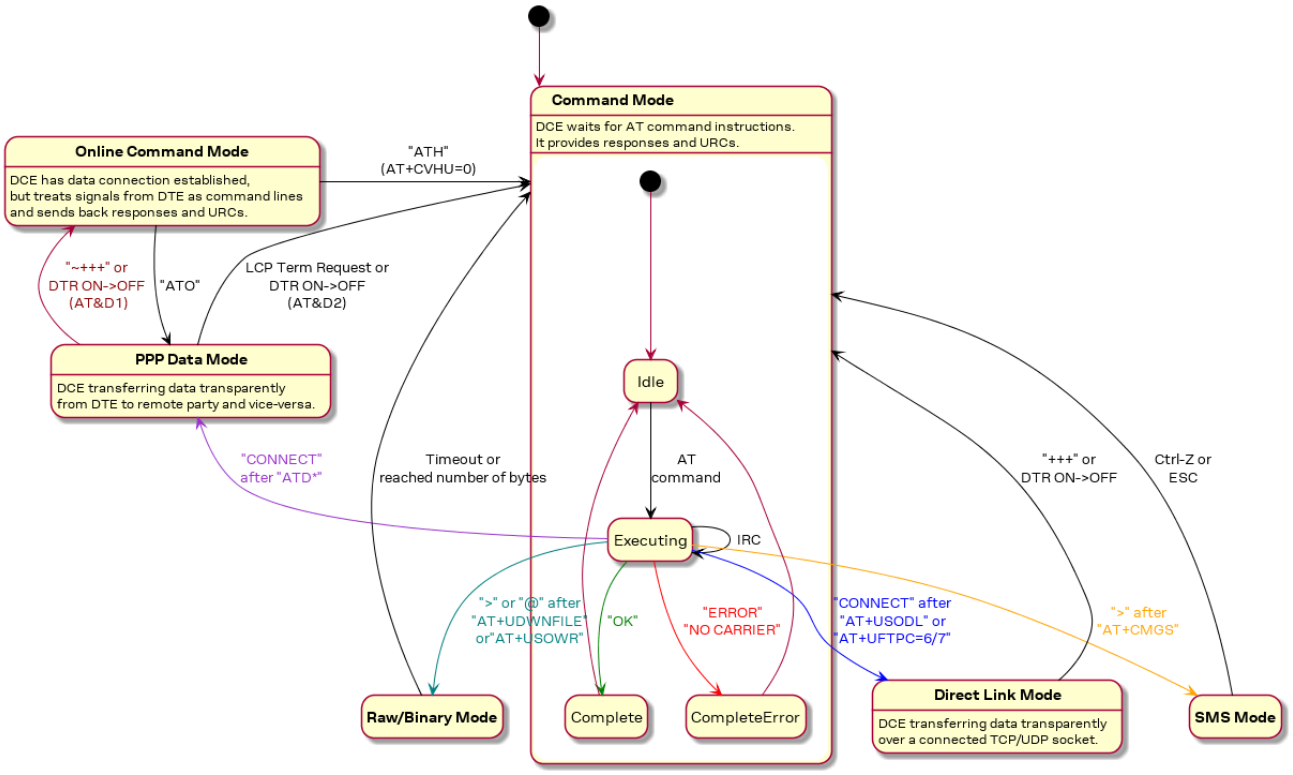

Figure 2: Module operating modes and actions causing mode transitions

4.2 Unsolicited result code

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

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

By default, all AT ports are enabled for the reception of URCs, it is possible to exclude some of them, by the `+UURCCONF` AT command available in SARA-R42 "01B" product versions. For more details, see section 4.2.1.1.

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

☞ URCs are sent to all available AT interfaces when the multiplexer functionality is applied.

Table 2 .shows some URC examples.

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

Table 2: URCs examples

4.2.1.1 URC over AT terminal configuration

The +UURCCONF AT command configures the list of the AT terminals enabled for URC reception.

This AT command is available in SARA-R42 “01B” product versions and it should be used by any application that is requiring URCs to be displayed only a specific set of AT terminals.

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

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

Table 3: +UURCCONF AT command example

☞ The +UURCCONF AT command is not supported by SARA-R42 “00B” product versions.

5 Local connectivity

5.1 Serial interface configuration

It is possible to switch between 3 serial interface configuration variants, using the +USIO AT command, as shown in Table 4.

Command	Response	Description
AT+USIO=0	OK	(Default configuration) AT on UART (9-wire: RXD, TXD, CTS, RTS, DTR, DSR, DCD, RI, GND), trace on USB.
AT+USIO=1	OK	AT on UART and AUX UART (5-wire: RX/TX, HW flow control, GND), trace on USB.
AT+USIO=4	OK	AT on UART (5-wire: RX/TX, HW flow control, GND), GNSS tunneling on AUX UART (5 wire: RX/TX, HW flow ctrl, GND), trace on USB.

Table 4: USIO variants description

Reboot the module to apply the new USIO configuration. For more details on +USIO AT command, see the SARA-R4 series AT commands manual [2].

AT+USIO=4 option is not supported by SARA-R422 modules.

URCs are sent to both UART and AUX UART interfaces when the AT+USIO=1 option is set.

It is not possible to have parallel activities on both AT terminals when the double UART configuration is selected, i.e. in AT+USIO=1. The only allowed parallel activity is present when it is defined a system architecture with a PPP dial-up on one port and AT commands on the other port.

The +URINGCFG AT command is not applicable when the AT+USIO=1 option is selected due to the fact that the RING line is not available at UART level in this configuration.

5.1.1 Auxiliary (AUX) serial interface configuration

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

Configuration changes are stored in the NVM and applied to the AUX UART interface at the next module boot.

Table 5 shows some examples of the +UUARTCONF AT command configuration. For more details, see the SARA-R4 series AT commands manual [2].

Command	Response	Description
AT+UUARTCONF=1,115200,3	OK	Set the desired baud rate and flow control mode for the auxiliary UART interface.
AT+UUARTCONF?	+UUARTCONF: 0,115200,3 +UUARTCONF: 1,115200,3 OK	Check the current settings for both the main UART and the auxiliary UART interfaces.
AT+UUARTCONF=?	+UUARTCONF: 1,(9600,19200,38400,57600,115200,230400,460800,921600),(0-3) OK	Visualize the possible settings to be applied in the auxiliary UART handling.

Table 5: +UUARTCONF variants description

The “Set” command is available only for the auxiliary UART interface.

☞ The “Read” command is available for both the main UART and the auxiliary UART interfaces.

☞ Baud rate 921600 bit/s is not supported by SARA-R42 “00B” product versions.

5.2 AT interface

AT commands can be issued to the module only via UART interface.

By default, the UART data rate is set to 115200 bit/s. Autobauding is not supported by SARA-R4 series modules.

5.2.1 Set a fixed baud rate

Table 6 shows how to set a different baud rate for the main UART by the +IPR AT command.

Command	Response	Description
AT+IPR=57600	OK	Set UART speed to fixed value 57600 bit/s. Cellular module response is sent at 115200 bit/s, i.e. at the original baud rate value.
After the “OK” final result code, wait for at least 200 ms before issuing a new AT command, to guarantee proper baud rate reconfiguration. Then send commands at the speed just set (57600 bit/s in the example).		
The new selected baud rate is immediately applied, a device reboot is not needed.		
AT+IPR?	+IPR:57600 OK	Check the current baud rate

Table 6: Setting a fixed baud rate example

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

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

☞ If using the Direct Link mode in downlink, it is advisable to apply 460800 bit/s as fixed baud rate.

☞ Baud rate 921600 b/s is not supported by SARA-R42 “00B” product versions.

5.3 Multiplexer (MUX)

SARA-R4 series modules support the multiplexer functionality on the UART physical link as defined in the 3GPP TS 27.010 [13]. This makes it possible to have multiple simultaneous sessions (virtual channels) over the single UART interface.

The following virtual channels are defined:

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

For further details about the usage of multiplexer with SARA-R4 series modules, see the Mux implementation in cellular modules application note [8].

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

[1] Not supported by SARA-R422 modules

☞ It is not possible to have parallel activities on AT terminals when the multiplexer is activated through the +CMUX AT command. The only allowed parallel activity is present when it is defined a system architecture with a PPP dial-up on one port and AT commands on the other port.

☞ URCs are sent to all available AT interfaces when the multiplexer functionality is applied.

☞ The multiplexer protocol is not supported in the configurations having the AUX UART interface enabled (for example, +USIO: 1, +USIO: 4).

5.4 Point-to-point protocol (PPP)

Data (PSD) calls are possible over both primary UART and auxiliary UART interfaces.

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

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

Further information about PPP dial-up establishment can be found in the Internet applications development guide application note [5] and in the EVK-R4 user guide [11].

5.5 Generic guidelines

To properly configure local connectivity, consider the following steps:

1. Set the required connectivity variant at first use, via the +USIO AT command.
2. Configure the GPIOs based on the set variant (especially in reference to the **RI** line), via the +UGPIOC AT command.
3. Configure the power saving control mode based on the set variant, via the +UPSV AT command. Moreover, in power saving configurations, it is advisable to set the RING line through the +URINGCFG AT command for asserting this line to properly detect incoming SMS and incoming data (PPP, sockets, FTP in Direct Link mode). This prevents from loosing data when the power saving is enabled, i.e.:
    - the DTR line is de-asserted, if the AT+UPSV=3 is applied;
    - the AT inactivity timer (6 secs) expires if the AT+UPSV=4 is applied.

6 MNO profiles

MNO profiles provide a powerful and flexible method to configure the SARA-R4 series module to seamlessly work with the SIM of the selected network operator.

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

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

Use the `+UMNOPROF` AT command to select a profile for the network operator. For more details of the `+UMNOPROF` AT command and the MNO profile settings, see the SARA-R4 series AT commands manual [2].

6.1 Using MNO profiles

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

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

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

6.2 Modifiable parameters

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

- `+UBANDMASK` Band mask
- `+CGDCONT` APN and PDP type
- `+URAT` Radio access Technology

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

☞ Usually, the APN will be accepted also when in roaming, but bands might need to be enabled to search for alternative PLMNs.

After setting the MNO profile the application may want to also modify the Radio Access Technology list and Band Mask.

Possible reason for setting `+URAT` may include:

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

☞ The US MNO profiles (AT&T, Verizon and FirstNet) activate only the LTE Cat M1 as Radio Access Technology. Accordingly, if the customer device is designed to go roaming to other countries or continents, it could be necessary to manually activate the NB-IoT and 2G RATs. Note that these

technologies have not to be used in U.S. because they are not certified for the referred network providers.

Possible reasons for setting +UBANDMASK may include:

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

6.3 MNO profile setting examples

Do not: set the MNO profile while the module is registered (Table 7)

Command	Response	Description
AT+CMEE=2	OK	Enable verbose error result code.
AT+COPS?	+COPS: 0,0,"00101",7 OK	Module is currently registered.
AT+UMNOPROF=100	OK	Do not set MNO profile while module is registered.

Table 7: Wrong way of setting the MNO profile

Do: de-register the module before setting MNO profile, then reboot it to apply the setting (Table 8)

Command	Response	Description
AT+CFUN=0	OK	Turn-off radio functionality, the module will de-register.
AT+UMNOPROF=100	OK	Set MNO profile for Standard Europe.
AT+CFUN=15	OK	Perform a module reset. After reboot, the MNO profile 100 settings are applied.

Table 8: Correct way of setting the MNO profile

6.4 Global profile (+UMNOPROF: 90)

This is the default profile for the SARA-R422 / SARA-R422S / SARA-R422M8S / SARA-R422M10S modules, with all supported bands set as enabled on all available RATs (LTE-M, NB-IoT, GSM/EGPRS).

☞ The LwM2M client is disabled by default in the Global profile of SARA-R42 "01B" product versions.

6.5 Standard Europe profile (+UMNOPROF: 100)

The MNO profile 100 should be used as the basis for all other MNOs in Europe outside of ones explicitly referred in other profiles. 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 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 roaming SIMs.

☞ The LwM2M client is disabled by default in the Standard Europe profile of SARA-R42 "01B" product versions.

6.6 AT&T profile (+UMNOPROF: 2)

SARA-R42 in AT&T configuration (+UMNOPROF: 2) is factory-programmed with a blank string for the <APN> at default context <cid>=1 as per AT&T requirement, the user must set the custom APN (which might be different for M2M and consumer SIM cards) used for live AT&T network attach via the +CGDCONT set command. This setting is persistent. For more details, see the SARA-R4 series AT commands manual [2].

Per AT&T requirement, LwM2M predefines a +CGDCONT context with factory-programmed values:

- <cid>=2: Ipv4V6,"attm2mglobal"
  - This is used for LwM2M data connection to the AT&T server for device management purposes. This APN entry shall not be deleted/changed by user.

☞ SARA-R42 is certified AT&T for LTE Cat M1 only. Accordingly in U.S. it is allowed to access only this RAT, while in roaming conditions outside North America area, it is possible to manually activate also the NB-IoT and 2G RATs and to apply desired configurations through suitable AT commands (e.g. +URAT, +UBANDMASK, etc.).

☞ The AT&T profile is not supported by SARA-R42 "00B" product versions.

☞ The LwM2M client is disabled by default in the AT&T profile of SARA-R42 "01B" product versions.

6.7 Verizon profile (+UMNOPROF: 3)

Per Verizon requirement, the initial EPS bearer and the EPS bearers used by BIP and LWM2M are defined by default and are aligned to the entries of the VZW APN table. For more details, see +VZWAPNE AT command description in SARA-R4 series AT commands manual [2].

SARA-R42 in Verizon configuration (+UMNOPROF: 3) is factory-programmed with a blank string for the <APN> at default context <cid>=1. The proper APN for <cid>=1 (e.g. a static APN related to the UICC subscription) will be assigned by Verizon during the LTE attach and shall be primarily used for user data connectivity. The APN for the other <cid>s can be updated by Verizon via LwM2M provisioning. Table 9 lists the descriptions of <cid>s in Verizon configuration.

<cid> (context id)	Description
1	Initial EPS bearer, it corresponds to the first record of VZWAPNE.
2	Corresponds to the Class 2 record of the VZWAPNE and it is used by BIP.
3	Corresponds to the Class 3 record of the VZWAPNE.
4	Corresponds to the Class 4 record of the VZWAPNE and it is used for the VZW Application PDN.
5, 6, 7	Correspond, respectively, to the Class 5, Class 6, and Class 7 records of the VZWAPNE.

Table 9: <cid>s description in Verizon MNO profile

The +CGDCONT read command shows the EPS bearers with <cid> in range 1-7. They cannot be modified or undefined with +CGDCONT, nor deleted with +CGDEL AT command.

☞ SARA-R42 is certified Verizon for LTE Cat M1 only. Accordingly in U.S. it is allowed to access only this RAT, while in roaming conditions (outside North America area) it is possible to manually activate also the NB-IoT and 2G RATs and to apply desired configurations through suitable AT commands (e.g. +URAT, +UBANDMASK, etc.).

☞ The Verizon profile is not supported by SARA-R42 "00B" product versions.

☞ The LwM2M client is enabled by default in the Verizon profile of SARA-R42 "01B" product versions.

6.8 GCF-PTCRB profile (+UMNOPROF: 201)

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

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

6.9 FirstNet profile (+UMNOPROF: 206)

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

Per FirstNet requirement, LwM2M predefines a +CGDCONT context with factory-programmed values:

- `<cid>=2: Ipv4V6,” attiotfirstnet.fn”`
  - This is used for LwM2M data connection to the FirstNet server for device management purposes. This APN entry shall not be deleted/changed by the user.

☞ SARA-R42 is certified FirstNet for LTE Cat M1 only. Accordingly in U.S. it is allowed to access only this RAT, while in roaming conditions (outside North America area) it is possible to manually activate also the NB-IoT and 2G RATs and to apply desired configurations through suitable AT commands (e.g. `+URAT`, `+UBANDMASK`, etc.).

☞ The FirstNet profile is not supported by SARA-R42 “00B” product versions.

☞ The LwM2M client is disabled by default in the FirstNet profile of SARA-R42 “01B” product versions.

7 Network registration

At power-on the module reads the information in the currently selected MNO profile. It will use this information to configure which bands to scan, the radio access technology to use if more than one is supported, and other attach parameters like APN.

Once the module has found a suitable cell to camp on, it will start the registration process. Depending on the current PLMN, during the registration the device can be provisioned with the APN or the APN must be provided by the host application as part of the persistent settings.

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

7.1 RAT selection

To select the RAT to be used by the module (LTE Cat M1, NB-IoT or EGPRS), issue the `+URAT` AT command.

Before changing the RAT selection, set the module to minimum functionality via `AT+CFUN=0` command. To make the setting effective, reboot the module with the `AT+CFUN=16` command. Table 10 shows an example of the procedure.

Command	Response	Description
`AT+URAT?`	`+URAT: 7` `OK`	Query the currently set RAT. Currently selected RAT is LTE Cat M1.
`AT+CFUN=0`	`OK`	Set the modem to minimum functionality.
`AT+URAT=8`	`OK`	Change RAT selection to NB-IoT.
`AT+CFUN=16`	`OK`	Reboot the module to make the change of RAT selection effective.
		Wait for module to reboot.
`AT+URAT?`	`+URAT: 8` `OK`	Query the currently set RAT. Currently selected RAT is NB-IoT.

Table 10: Example of changing RAT selection from LTE Cat M1 to NB-IoT

7.1.1 PLMN and RAT selection rules

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

For more details, see section 7.6.

7.1.2 RAT automatic scan

When working in multi-RAT (LTE Cat M1 plus NB-IoT and/or 2G), it could happen that the module does not select the highest priority RAT according to `+URAT` settings (e.g. NB-IoT or EGPRS according to `AT+URAT=7,8,9` setting) due to its current unavailability in the selected network.

Considering this aspect, SARA-R42 series modules present a functionality based on the `+URATSCAN` AT command that periodically triggers a network scan to look for a RAT with a higher priority than the current one. The RATs priority is defined through the `+URAT` configuration and the default scan time is set to 60 minutes. Note that:

- The periodic scan triggered by +URATSCAN causes a temporary out-of-service (OOS) period in which the device is not reachable, e.g. for SMSs. This must be considered by user applications, as more configured bands (see +UBANDMASK), more time to complete the network scan;
- In SARA-R42 series modules, the +URATSCAN AT command triggers a network scan also in data traffic mode, so there could be a temporary suspension of this activity.

☞ It is advisable to apply a suitable tuning at customer side: there could be a trade-off between the need to select a RAT with a higher priority and the requirement to decrease as much as possible the OOS time.

7.2 Band configuration

The module can scan over several bands to find a network to attach to. The host application can limit the scanning to specific bands to shorten the time to find a network.

Use the +UBANDMASK AT command to specify these bands as an 8-byte bitmask. In the bitmask, setting the bit at (band-x) position to 1 enables the scan of band x, as shown in Figure 3.

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

Use these values for AT+UBANDMASK

Figure 3: +UBANDMASK bitmask creation examples

☞ Each MNO profile defines a set of bands to scan on.

7.2.1 Scan time

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 faster.

Because NB-IoT allows 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 LTE Cat M1, but there are no NB-IoT networks, the module may take a few minutes per band to complete the NB-IoT scanning before re-trying the LTE Cat M1 RAT scan. If a global roaming profile is used, the application can rely on the automatic band scan and PLMN search done by the device at national border crossings. Alternatively, to optimize power consumption and reduce the impact of band scan and PLMN searches in out of coverage situations, the application shall reduce the supported bands based on regional information provided by the module via AT command interface and change bands with some hysteresis.

Regarding the possibility to perform network scans when the module is in automatic selection, i.e., AT+COPS=0, the following points must be considered, especially in roaming conditions:

- The RATs are considered according to the +URAT AT command settings about the preference order (<1stAcT>, <2ndAcT> and <3rdAcT>);
- The preference order of the RATs could be overruled by the +CPOL preferred operator list and the related <AcT>.

7.2.1.1 OOS scan timings

The scan algorithm is implemented when attempting to gain service at power-up and when the out-of-service (OOS) condition is detected. A full system scan is interspersed with sleep intervals to reduce power consumption. The algorithm starts with a sleep time of 30 s which is applied 10 times, then the sleep time is incremented to 45 s, which again is applied for another 10 times, finally the sleep time is set to 60 s.

Each full system scan starts with the search of recently used cells, if available, which are coming from an internal database updated every time the devices find full service on a cell. Then the full system scan continues triggering a band scan for all enabled bands. At each step, the full scan considers all the enabled RATs ordered according to the configured relative priority. RAT and band settings can be configured with the +URAT and +UBANDMASK AT commands if not locked.

This algorithm is maintained until a suitable cell providing full or limited service is found and the device can camp on it.

To lower the power consumption, it is recommended to implement an algorithm on the application processor to switch the device off (or set it to minimum functionality) if it cannot gain service for a long time and switch it on (or set it to full functionality) after a while to try to get full service again. The duty cycle can be selected by the host application based on the tradeoff between power consumption and maximum tolerable delay before regaining cellular coverage.

7.3 First time registration setup

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

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

☞ The AT+COPS=2/0 cycle shall be used when looking for a more suitable PLMN, as per SIM settings related to the preferred operator list available through the +CPOL AT command.

☞ The AT+COPS=2/0 cycle triggers a high priority PLMN scan, so this cycle shall be avoided in roaming conditions.

7.3.1 PAP/CHAP

If PAP or CHAP authentication is to be configured, the +UAUTHREQ AT command shall be entered.

If the authentication is required on the initial default bearer, the setting shall be entered in de-registered state.

7.3.2 Change of PDN settings (APN name and PDP type)

To change the PDN settings for the initial default EPS bearer established during LTE attach, edit the <cid>=1 PDN by the +CGDCONT AT command, as shown in Table 11.

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

Command	Response	Description
	+CEREG: 1,"0001","01a2d001",7 +CGEV: ME PDN ACT 1	

Table 11: Change of PDN settings example

7.3.3 Attach types

All profiles use combined attach (CS & PS), if successful, both data and SMS services are allowed. If LTE attach is successful for EPS only services, still SMS can be supported (the so called "SMS only" case). If LTE attach is not successful for SMS, the module can try registration on a different RAT (e.g. 2G RAT).

The +USVCDOMAIN AT command can be used to change how the module attaches to the network if the factory-programmed attach type is not accepted by the network.

7.3.3.1 NB-IoT networks: ePCO handling

On NB-IoT, where CP CioT EPS optimizations are mandatorily active, the 3GPP standard prescribes that the extended Protocol Configuration Options (ePCO) container is used in Network Access Stratum (NAS) messaging when attaching to an LTE network. Some NB-IoT 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 example, for NB-IoT networks known to not support ePCO, or when +CGCONTRDP AT command does not return any DNS in NBIoT, it is recommended to use +UCFGCIOT AT command to disable the ePCO feature and fallback to PCO negotiation, as shown in Table 12.

Command	Response	Description
AT+COPS?	+COPS: 0,0,"NB-IoT Network",8 OK	Module registered on NB-IoT network.
AT+CGDCONT?	+CGDCONT: 1,"IP","default","192.168.20.2",0,0,0 OK	The module activated the EPS bearer with a valid IP address.
AT+CGCONTRDP	+CGCONTRDP: 1,5,"default","192.168.20.2","192.168.20.1","","" OK	DNS references not available in the +CGCONTRDP AT command.
AT+UCFGCIOT=3,0	OK	Disable the ePCO feature through the +UCFGCIOT AT command.
AT+CFUN=15	OK	Reboot the module to apply the configuration.
AT+COPS?	+COPS: 0,0,"NB-IoT Network",8 OK	Module registered on NB-IoT network.
AT+CGDCONT?	+CGDCONT: 1,"IP","default","192.168.20.2",0,0,0 OK	The module activated the EPS bearer with a valid IP address.
AT+CGCONTRDP	+CGCONTRDP: 1,5,"default","192.168.20.2","192.168.20.1","185.215.195.114" OK	DNS references now available in the +CGCONTRDP AT command.

Table 12: ePCO feature disabling

7.3.4 Radio Policy Manager

SARA-R4 series modules implement the Radio Policy Manager (RPM) feature according to GSMA connection efficiency TS 34 [14]. RPM aims to prevent cellular devices to aggressively try registration or PDP context activation procedures in case of permanent failures (e.g. "invalid UE" or "EPS services not allowed"), which are usually due to subscription restrictions, in addition to standard 3GPP retry algorithms. Since these aggressive behaviors can cause network overload and service outage, some

MNOs require to have RPM active by default: the RPM feature is enabled only on specific MNO profiles (for more details, see appendix C of SARA-R4 series AT commands manual [2]), but they can be enabled via AT commands on other MNOs requiring it.

7.3.4.1 Management of SW resets

RPM limits the number of user-initiated module resets per hour following a permanent attach reject cause. RPM might block the following AT commands and provide an error result code: `AT+CFUN=15`, `AT+CFUN=16`, `AT+CFUN=19`, `AT+CFUN=1,1` and `AT+CFUN=4,1`, and `AT+CPWROFF`.

Eventually, RPM will again allow these commands and can even autonomously trigger a SW reset: timers and maximum counters can be derived from the MNO SIM card (so they can be even OTA updated) or are retrieved from the NVM (at most 1 module reset per hour is usually allowed per GSMA). RPM counters are cleared after a successful registration.

7.3.4.2 Management of PDP context activations

RPM also limits:

- The maximum number of successful PDP context activations on the same APN (e.g. for Deutsche Telekom (DT) MNO the limit is 30).
- The maximum number of PDP context activations requests per hour following a PDP context activation request ignored by the network (e.g. for DT it is 60).
- The maximum number of PDP context activations requests per hour following a PDP context activation request rejected with a “permanent” or a “temporary” reject cause, e.g. for Deutsche Telekom they are 30 and 60 respectively.

If PDP context activation is blocked by RPM, the `AT+CGACT=1,<cid>` command will fail with an error result code and the dial-up on a non-active `<cid>` will not be established.

Since the LTE attach usually implies a PDN connectivity activation, also LTE registration cycles triggered, for example by `AT+CFUN=0/1`, are subjected to the same limitations (e.g. for Deutsche Telekom maximum 30 attach/detach cycle per hour are allowed). However, once the limit is exceeded, the module will not register to the network for the following hour and no specific error will appear.

7.4 +UMACQOSTMR timer configuration

The `+UMACQOSTMR` AT command allows configuration of a proprietary MAC layer timer that acts as an 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 as 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.

For details on the default `+UMACQOSTMR` settings, see the MNO profiles section in the appendix of the SARA-R4 series AT commands manual [2].

When using network simulators, to perform certain types of measurements there may be a need to stay in local RRC connected state. See section **Error! Reference source not found.** for details for guidance to disable the timer in such situations.

7.5 Registration monitoring

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

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

☞ Independently of the selected RAT, always issue the AT+CGACT=1,<cid> command on used context <cid> even if the +CGDCONT AT command returns that the context is still active with a valid IP address. This is highly recommended to activate the PS data connection avoiding possible conflicts between applications.

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

7.5.1 Detecting the access technology

SARA-R4 series modules can connect to different types of access technologies, i.e. LTE Cat M1, NB-IoT and GPRS. 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 AT command. The +COPS AT 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, i.e. +CEREG for LTE (Cat M1 or NB-IoT) and +CGREG (GPRS).

Host applications should always enable the URC for +CEREG and +CGREG. When the module registers on the network the application can read the access technology type from these URCs.

Basic operation are:

Command	Response	Description
AT+CEREG=1	OK	Set URC for LTE (apply AT+CEREG=2 for more detailed info)
AT+CGREG=1	OK	Set URC for GPRS (apply AT+CGREG=2 for more detailed info)
<Wait for URC>		
AT+COPS?	+COPS: 0,0,"Cat-M1 Network",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, accordingly it is advisable to enable the +CREG URC too, by the AT+CREG=1 command or, alternatively, the AT+CREG=2 command for more detailed information.

7.5.2 PS connections at RAT change

If the module registers in LTE Cat M1 and NB-IoT networks, it will automatically activate the default bearer PDP context, <cid>=1. Any other PDP context the host has configured shall be manually activated. If the module attaches on the 2G network, this might require the host to manually activate a PDP context, unless the module reselected 2G from LTE Cat M1 or NB-IoT, where it already had an IP address whose assignment has been maintained on the 2G RAT.

When the module changes the RAT in registered state, the module will usually experience a temporary OOS condition while it is synchronizing with the new cell of the different RAT. This condition is reported via the +CGEV NW DETACH URC and +CGATT:0 PS status, but PDP contexts and socket connections are just suspended and +CGDCONT? read command will return the assigned IP addresses and +CGACT? the active PDP contexts.

7.6 Mobility scenarios

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

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

7.6.1 Roaming conditions

If mobility implies crossing national borders or changing the PLMN, it is likely that the new PLMN will force the module to reattach. This can also occur on the RPLMN, for example, when the network needs to refresh IP addresses. If the module reselects a 2G cell and registers on a 2G PLMN, it is necessary to re-establish the PDP context to restore the services requiring cellular connectivity.

If UE is to do data traffic in roaming conditions and based on the SIM card contents there might be a higher priority PLMN in the same country (i.e., with the same MCC as the current RPLMN), then 2 minutes after the registration the device will schedule a PLMN search to find a better roaming partner. This might lead to temporary unavailability of the cellular connectivity and can be handled by the host application in different ways depending on the SARA-R42 series variants. For more details, see section 7.6.1.1 and 7.6.1.2.

7.6.1.1 SARA-R42 “00B” product versions

In the above scenario, the high priority PLMN scan scheduled 2 minutes after the first registration causes the abort of the GPRS connection if SARA-R42 “00B” module is camped on 2G, and the temporary suspension of the data traffic in all RATs as long as the PLMN scan is ongoing.

A possible solution to prevent the higher priority PLMN scan is to apply a manual PLMN selection as following:

1. Start the network registration with `AT+COPS=0` (automatic mode)
2. If the module is in roaming condition (`AT+CEREG?` or `AT+CREG?` or `AT+CGREG?` return 5 as registration status), the module shall be set in manual PLMN selection, i.e.:
   - Check the selected network in numeric format querying `AT+COPS?`
   - Manually configure the registration to this VPLMN (Visited PLMN) specifying also the current RAT in the `AT+COPS=1` instruction (e.g., `AT+COPS=1,2,"00101",7` if camped in LTE Cat M1 RAT)
3. When the module is in out-of-service condition, the automatic PLMN selection can be restored applying the usual AT commands sequence (`AT+CFUN=0; AT+COPS=0; AT+CFUN=1`) and coming back to point 1 of the proposed workaround

Alternatively, the user preferred operator list can be edited with the `+CPOL` AT command, but not all M2M SIM cards include the related file.

7.6.1.2 SARA-R42 “01B” product versions

In the above scenario, the SARA-R42 “01B” product versions benefit from the following improvements:

- In 2G, higher priority PLMN scans are rescheduled as long as there is a running GPRS data session (more precisely, within about 1 minute since the last GPRS data packet has been exchanged with the cellular network).
- The periodicity of the higher priority PLMN search can be customized with the +UHPPLMN AT command. Moreover, a specific URC notifies the application when this search has been triggered.

Command	Response	Description
AT+UHPPLMN?	+UHPPLMN: 1,60,0 OK	Check the +UHPPLMN AT command configuration (initially, the value in minutes is retrieved from SIM card)
AT+UHPPLMN=1,120,1	+UHPPLMN=1,120,1 OK	Set the HPPLMN search timer to 60 minutes and enable the URC reporting when the periodic search is triggered
AT+CFUN=15	OK	Reboot the module to apply the setting
		Wait for 120+2 minutes after registration in roaming
	+UHPPLMN: 3600	URC visualized when the periodic search has been triggered, with indication of the actual timer value expressed in seconds

Table 13:+UHPPLMN AT command example

7.6.2 Data traffic in roaming

Performing data traffic in roaming conditions could be expensive, due to possible extra costs applied by VPLMNs. In this scenario, if it is needed to limit data traffic, use AT+UDCONF=76 command with proper syntax. In this way the selected PDP context cannot send data when roaming on a network.

7.6.3 Mobility Management procedures

Mobility management procedures are different, depending on the state of the radio connection:

- Connected Mode Mobility (CMM) is handled by the eNodeB in LTE Cat M1. The UE is instructed by the eNodeB to provide measurement reports on neighbor cells so that the network can decide if, and when, the radio resource control (RRC) connection shall be handed over to another cell.
  - The network itself will allocate gaps in the downlink transmission to allow the device to perform the intra-band or inter-band measurements: this will impact the downlink throughput.
  - If the eNodeB does not support CMM, or current RAT is NB-IoT or 2G, the RRC connection will be released at cell change due to radio link failure and it will be re-established by the device on the new selected cell. Radio link failures usually implies loss of uplink or downlink packets.
- Idle Mode Mobility is handled by the UE using information transmitted in the System Information Blocks (SIB) broadcast by the cellular network within the cell. In idle mode, the UE will make measurements of neighbor cells and, based on the cell reselection criteria read in the SIBs, it may choose another serving cell to synchronize with.

8 Deep-sleep mode, PSM and eDRX

8.1 Deep-sleep mode

Deep-sleep mode is a state in which the module keeps running at negligible current (for definitions and power consumption characterization, see the SARA-R4 series system integration manual [3]). The module is in minimum functionality and is not responsive to AT commands. SIM PIN check should not be used along with deep-sleep, since it would prevent cellular connectivity restore at deep-sleep exit until PIN re-insertion.

Deep-sleep mode can be enabled via `AT+CPSMS=1` AT command and used in three options, described in section 8.1.4. Each feature defines the periodicity of deep-sleep entry and exit cycles autonomously performed by the module. If the autonomous wake-up would be scheduled in less than 1 minute, the UE does not enter deep-sleep to compensate for boot penalty. The host application can monitor deep-sleep entry and exit cycles, as described in section 8.1.3, and foresee them (via the `+UCPSMS`, `+CEDRXRDP` and `+UPSMVER` AT commands in case of PSM deep-sleep, eDRX deep-sleep and OOS deep-sleep respectively). When the host application needs to interact with the module in deep-sleep state, e.g. to use the GNSS receiver, to issue AT commands or to send MO data, it can either wait the module to exit deep-sleep state autonomously or trigger an early wake-up via the **PWR_ON** pin. From a power consumption point of view the first solution is preferred, if possible, for GNSS receiver usage and AT commands issuing, whereas the second one should be used for MO data, waking-up the module just before it exits PSM or eDRX deep-sleep by itself when possible. After an early wake-up via the **PWR_ON** pin the host application should monitor the module has exited deep-sleep state (see section 8.1.3) and interact with it immediately, in no later than 10 s after deep-sleep exit.

To keep power consumption in deep-sleep extremely low, the only running module component in this state is a low power low accuracy clock. Being this clock inaccurate, it can be affected by an always negative drift, causing the time in deep-sleep to be shortened by no more than 1% of the expected deep-sleep duration. When exiting deep-sleep the module checks the network time and can immediately re-enter in deep-sleep if convenient from power consumption point-of-view.

When the module enters deep-sleep mode, it locally deactivates MUX and PPP, and is not responsive to AT commands. Any non NVM saved settings are lost. Timers, including application timers, are reset except for T3412 and throttling timers: T3402, sever network failure (SNF, Verizon specific), T3346, T3396, and T3245 (if it is configured in USIM), which are saved and restored at deep-sleep exit.

8.1.1 Deep-sleep and applications

Some embedded applications and features are aware of deep-sleep mode and can temporarily postpone the entrance into deep-sleep mode until all pending activities completed. Such activities include LwM2M, GNSS receiver usage and security, which may wait for server response; and the AT interface, which restarts a 6 s guard timer any time a character is received over UART. Application-initiated deep-sleep prevention can be monitored via the `+UUPSMR:2,<client_id>` URC.

Coverage Extension (CE) modes can also postpone the entry to deep-sleep mode. In extended coverage the network may release the RRC connection later than in normal coverage, to accommodate the many retransmissions related to the Coverage Extension (CE) mode currently assigned to the UE. This can be checked via the `+CEINFO` AT command and the `+CSCON` URC.

Some IP-based applications, e.g., MQTT, USOCK, UDNS, UFTP, HTTP, are not aware of deep-sleep mode and have no control over it. They might be negatively impacted by the UE entering in deep-sleep state during the data sessions such as UDP, TCP or secure sockets. For example, in case of PSM deep-sleep, the negative impact happens if the RRC connection is released and the T3324 expires while the UE is waiting for a network response. The network response delay can be a consequence of a temporarily server outage or packet loss in low coverage or mobility. Transaction duration can be

reduced by using UDP sockets instead of TCP ones, which also consume less power. Like IP based applications, asynchronous AT commands, like +UMQTTC or +UDWNFILE, have no control on deep-sleep which could be entered before the final result of the requested operation is received via URC.

The host applications that are un-aware of deep-sleep mode can temporarily prevent deep-sleep entry by issuing the AT+UPSMVER=,,,,1 AT command.

To postpone deep-sleep entry during a blocking AT command execution, AT commands can be issued on another virtual AT port. When possible, deep-sleep temporary preventing is preferred to the disabling and re-enabling of deep-sleep via the +CPSMS AT command, which would waste power in two extra deregistration-registration cycles.

8.1.2 Deep-sleep and roaming

When the module is registered on a roaming network (i.e., 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 an higher priority public land mobile network (HPPLMN). HPPLMN searches cause the module to exit deep-sleep and delay deep-sleep entry until search completion. HPPLMN searches can be disabled via the AT+UHPPLMN=0 AT command in SARA-R42 "01B" product versions.

8.1.3 Deep-sleep indications

The host application can monitor the entrance and exit from deep-sleep state in several ways:

- GPIO "module status indication", see the +UGPIOC AT command description in the SARA-R4 series AT command manual [2]
- **V_INT** monitoring
- +UUPSMR URC, issued when entering and exiting deep-sleep mode

8.1.4 Deep-sleep options

To recap, deep-sleep mode can be configured by the +CPSMS and +UPSMVER AT commands. Meaningful combinations are:

- +CPSMS=0: deep-sleep mode disabled (default setting).
- +CPSMS=1, +UPSMVER=,,,,0: deep-sleep mode enabled and deep-sleep entry possible.
- +CPSMS=1, +UPSMVER=,,,,1:deep-sleep mode prevented by the deep-sleep temporary disablement. The +UUPSMR: 2,6 URC is issued when deep-sleep entry is prevented.

When deep-sleep mode is enabled, it can be configured in three options:

1. OOS deep-sleep, see section 8.1.5
2. PSM deep-sleep, see 3GPP PSM feature described in section 8.2
3. eDRX deep-sleep, see 3GPP PSM feature described in section 8.3

The 3GPP PSM feature legacy usage involves periodic PSM deep-sleep entry. However, the feature can be also used without periodically entering PSM deep-sleep to match deep-sleep non aware applications needs (see PSM deep-sleep example). The 3GPP eDRX feature legacy usage does not involve periodic eDRX deep-sleep entry, which can be enabled to increase power savings (see eDRX deep-sleep example).

3GPP PSM and eDRX features can be used separately or together. In the latest case PSM and eDRX legacy usage applies, periodically entering PSM deep-sleep unless temporarily disabling it, while it is not possible to also enable eDRX deep-sleep (see eDRX deep-sleep example). OOS deep-sleep can be used with the other two deep-sleep options (see OOS deep-sleep example in section 8.1.5).

The following examples illustrate PSM deep-sleep and eDRX deep-sleep options usage. They assume the module is network registered; for instance, LTE Cat-M1 network registration is taken.

PSM deep-sleep

Command	Response	Description
AT+CLCK="SC",2	+CLCK: 0 OK	Verify if SIM PIN check is disabled, if not, disable it.
AT+UPSMVER?	+UPSMVER: 4,3,3,4,0 OK	Verify default values are set in the +UPSMVER AT command: PSM deep-sleep option selected (<psm_ver>=4) and deep-sleep temporary disablement not set (<temp_dis>=0). If not, set default values.
AT+CFUN=0 AT+CPSMS=1 AT+UPSMR=1 AT+CFUN=15	OK OK OK OK	Enable deep-sleep as well as +UUPSMR URC.
AT+CPSMS?	+CPSMS: 1,,, "00111000","00001010" OK	Read +CPSMS settings to see deep-sleep is enabled (<mode>=1) and, once PSM deep-sleep option selected by +UPSMVER, the 3GPP PSM feature request is enabled (PSM related timers are returned in the +CPSMS read response with non-null timer values).
AT+UCPSMS?	+UCPSMS: 1,,, "00111000","00001010",1 OK	Chek if the 3GPP PSM feature usage request has been granted (<mode>=1 in the +UCPSMS read response): only in this case the 3GPP PSM feature is used. PSM deep-sleep can be periodically entered as per 3GPP PSM feature timers (+UUPSMR: 1,1 displayed at PSM deep-sleep entry).
AT+UPSMVER=,,,,1	OK +UUPSMR: 2,6	Temporarily disable deep-sleep when needed due to deep-sleep non-aware applications usage. The 3GPP PSM feature is used but PSM deep-sleep mode is not entered.

eDRX deep-sleep

Command	Response	Description
AT+CLCK="SC",2	+CLCK: 0 OK	Verify if SIM PIN check is disabled, if not, disable it.
AT+UPSMVER?	+UPSMVER: 4,3,3,4,0 OK	Verify default values are set in the +UPSMVER AT command. If not, set default values.
AT+CPSMS?	+CPSMS: 0,,, "01100000","00000000" OK	Make sure default +CPSMS settings are set, if not, disable deep-sleep. Read +CPSMS settings to see deep-sleep is disabled (<mode>=0) and the 3GPP PSM feature request is disabled (PSM related timers are returned in the +CPSMS read response with null timer values despite non-null timer values are set).
AT+CFUN=0 AT+CEDRXS=2,4 AT+CFUN=15	OK OK OK	Enable the 3GPP eDRX feature request.
AT+CEDRXS?	+CEDRXS: 4,"1011","0011" OK	Read +CEDRXS settings to see the 3GPP eDRX feature request is enabled (eDRX related timers are present in the +CEDRXS read response).
AT+CEDRXRDP	+CEDRXRDP: 4,"1011","1011","0011" OK	Check if the 3GPP eDRX feature usage request has been granted (eDRX related timers are returned in the +CEDRXRDP response): only in this case the 3GPP eDRX feature is used. Being deep-sleep disabled eDRX deep-sleep is not periodically entered. Being 3GPP PSM feature disabled eDRX is used standalone (i.e., not in combination with PSM).
AT+CFUN=0 AT+CPSMS=1 AT+UPSMR=1 AT+CFUN=15	OK OK OK OK	Enable deep-sleep as well as +UUPSMR URC.
AT+CPSMS? AT+CEDRXS?	+CPSMS: 1,,, "00111000","00001010"	Read +CPSMS settings to see deep-sleep is enabled (<mode>=1) and, being PSM deep-sleep option selected by

Command	Response	Description
	OK +CEDRXS: 4, "1011","0011" OK	+UPSMVER, the 3GPP PSM feature request is enabled. Read +CEDRXS settings to see the 3GPP eDRX feature request is also enabled. There are 3 possible cases (please refer to sections 8.2.3 and 8.3.4 to check which one applies). • If only eDRX feature is granted, it is used standalone, without entering eDRX deep-sleep. • If only PSM feature is granted, PSM deep-sleep is periodically entered. • If both eDRX and PSM features are granted, eDRX is used in combination with PSM and PSM deep-sleep is periodically entered.
AT+UPSMVER=8 AT+CFUN=15	OK OK	Select eDRX deep-sleep option.
AT+CPSMS? AT+CEDRXS?	+CPSMS: 1,,, "01100000","00000000" OK +CEDRXS: 4,"1011","0011 " OK	Read +CPSMS settings to see deep-sleep is enabled (<mode>=1) and the 3GPP PSM feature request is disabled. Read +CEDRXS settings to see the 3GPP eDRX feature request is enabled. If eDRX feature is granted, it is used standalone, periodically entering eDRX deep-sleep.
AT+UPSMVER=,,,,1	OK +UUPSMR: 2,6	Temporarily disable deep-sleep when needed due to deep-sleep non-aware applications usage.

8.1.5 Deep-sleep state in OOS

In prolonged OOS conditions, the module will continue to perform full PLMN scans until service is gained. OOS deep-sleep enables power saving in this case: after several unsuccessful network scans, the module enters the power-efficient deep-sleep state for a certain period. Both the number of scans performed in a row and the deep-sleep duration can be configured via the +UPSMVER AT command. The same AT command can disable the feature.

OOS deep-sleep

Command	Response	Description
AT+UPSMVER?	+UPSMVER: 4,3,3,4,0 OK	Check default OOS deep-sleep configuration applies: OOS deep-sleep option selected (<oos_scans>), 3 full scans performed (<oos_scans>), 4 min of sleep (<deep_sleep_oos_dur>). If not, set it.
AT+CFUN=0 AT+CPSMS=1 AT+UPSMR=1 AT+CFUN=15	OK OK OK OK	Enable deep-sleep to also enable OOS deep-sleep option.
AT+UPSMVER=,,0 AT+CFUN=15	OK OK	If needed, disable OOS deep-sleep option (<oos_scans>=0) keeping deep-sleep enabled: deep-sleep can be used in PSM deep-sleep and eDRX deep-sleep options.

8.2 Power Saving Mode (PSM)

PSM is a 3GPP standard feature that minimize power consumption for devices that require sporadic cellular network access. Instead of switching off the module at the end of the data transfer, if PSM is enabled with the +CPSMS AT command, a device can negotiate lasting time periods up to 413 days, during which keepalive notifications can be postponed and the module can stay registered to the network.

Meanwhile, pending mobile terminated (MT) traffic indications, such as SMS or small data packets, are likely to be stored at the network side. This allows devices to skip paging reception and enter the minimum functionality PSM deep-sleep mode.

To send any pending MT traffic from the application server (AS) to the application client (AC), applications are suggested to implement a pull mechanism:

1. The AS can send a small MT trigger (SMS or small data packet). The trigger is NW-buffered and delivered to the AC at UE PSM exit.
2. Upon trigger reception the AC sends a mobile originated (MO) pull message to the AS.
3. Upon pull message reception the AS completes the MT data delivery. Optional MO acknowledgement can follow.

The host application is suggested to configure PSM on the module before NW registration. The application-configured requested PSM settings are NVM persistent and used at any registration procedure, periodic or due to mobility in other areas, which is seen as a new negotiation opportunity. The requested PSM settings can be configured via the +CPSMS AT command, whereas the PSM settings assigned by the network, which are the used one, can be discovered via the +CEREG URC and the +UCPSMS AT command. If PSM is not granted by the network, the module cannot use PSM. If so, the host application could power on and off the module with desired periodicity to save power.

Assuming the module is registered on an LTE Cat.M1 or NB-IoT network, two timers determine the entrance into PSM deep-sleep mode. Both timers start when the NW releases an existing RRC connection, and are reset, if a new RRC connection is established before timer expiry. RRC connection setup and release can be monitored via the +CSCON URC

- T3324, the active timer, the shorter one. At T3324 expiry, the module can enter the PSM deep-sleep mode, and it enters PSM deep-sleep as soon as the module completes any pending activity. If the NW needs to send any MT data, e.g. MT trigger, then it always pages it before the active timer expiry. If the NW does not allow the UE to use PSM feature, it does not assign the active timer.
- T3412, the periodic Tracking Area Update(TAU) timer, the longer one. At T3412 expiry, the module exits PSM deep-sleep and performs a TAU procedure. The T3412 timer comes with two timer values: the legacy one and the optional extended timer value. The UE requests an extended timer value whenever requesting the PSM feature usage and uses the extended timer value whenever NW-assigned - the NW can assign an extended timer value even if not granting PSM. By default, the cellular network sets the T3412 duration to 54 minutes, while the extended timer duration can be up to 413 days long.

When PSM is granted by the network, context retention is used. At PSM deep-sleep exit no LTE attach is needed, previously activated EPS bearers and IP addresses are locally restored. The module can directly start a MO data or signaling transmission. A TAU procedure is started at PSM exit due to T3412 expiry. If the host application needs to send MO data before T3412 timer expiry it can early wake-up the module and directly send MO data.

8.2.1 Configuration recommendations

The selection of the requested T3412 timer value is a trade-off between power consumption and the tolerated MT data delay, which is the limit factor for the T3412 timer duration. When using PSM it is recommended to request a T3412 timer extended value of at least 4 hours. If no MT data is considered in the application design, power can be minimized requesting the longest possible 413 days timer duration.

The selection of the requested T3324 timer value is a trade-off between power consumption and responsiveness. Low values save more battery life making it possible for the UE to enter PSM deep-sleep mode more quickly. High values of T3324 give some margin to the application server (AS) to respond to MO data sent by the UE before it enters PSM. AS responses to MO data can be both MO data acknowledgements as well as MT data delivery as a response to MO pull messages.

As a rule of thumb, the maximum suggested T3324 is 10 times shorter than T3412; the minimum suggested T3324 should allow reliable paging if MT data or acknowledgements delivery is considered

in the application design. The time needed to reliably deliver paging to the UE depends on whether the network uses discontinuous reception (DRX) and can be determined as 2*DRX cycle + 10 s (buffer time at network side), which amounts to 16 s in case of 2.36 s long DRX cycles (see the +UCGED AT command description to read DRX settings). If MT data or acknowledgements are not considered in the application design, or in case the RRC inactivity timer adopted by the network matches the application needs related to the paging delivery reliability, a 0 s T3324 timer duration is also allowed.

Customers are advised to test both parameters to come to a value that best fits their use case and requirements regarding power consumption, MT data delay, and reliability.

8.2.2 Timer values

8.2.2.1 Encoding of timer T3412

The extended TAU timer is encoded as GPRS timer 3 IE (see TS 3GPP TS 24.008 [12]).

Bits 5 to 1 represent the binary coded timer value. Bits 6 to 8 define the timer value unit for the GPRS timer and are encoded 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
    1 1 1 value indicates that the timer is deactivated
```

For example: "**010**00111" = 7 **x 10 hours** = 70 hours

☞ If the timer is not received in an integrity protected message (this can happen for example on lab setup on network simulators), the 110 unit shall be interpreted as 1 hour.

☞ If the 111 unit is used, the T3412 extended value is considered as not included in the message.

If the network does not grant an extended periodic TAU timer value, the standard periodic TAU timer value can be decoded using the T3324 timer table, as they share the same encoding. The standard or extended value encoding of the periodic TAU timer is indicated by the <Assigned_Periodic_TAU_Format_Type> parameter of the +UCPSMS AT command response.

8.2.2.2 Encoding of timer T3324

The Active Time T3324 is encoded as GPRS timer IE (see TS 3GPP TS 24.008 [12]).

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 decihours (6 minutes)
    1 1 1 value indicates that the timer is deactivated
```

☞ All other values are to be interpreted as multiples of 1 minute.

For example: "**000**00100" = 4 **x 2 s** = 8 s

8.2.3 Example of PSM configuration

This example illustrates how the 3GPP PSM feature, disabled by default, can be configured and how to check NW assigned settings.

Command	Response	Description
AT+CLCK="SC",2	+CLCK: 0 OK	Verify if SIM PIN check is disabled, if not, disable it.
AT+CEDRXS?	+CEDRXS: OK	Verify if eDRX is disabled, if not, disable it.
AT+UPSMVER?	+UPSMVER:4,3,3,4,0 OK	Verify default values, with PSM deep-sleep option selected, are set in the +UPSMVER AT command. If not, set default values.
AT+CSCON=1 AT+UPSMR=1	OK OK	Enable +CSCON and +UUPSMR URCs.
AT+CFUN=0 AT+CPSMS=1,,,"00111000","00001010" AT+CFUN=15	OK OK OK	Enable the 3GPP PSM feature requests. Set PSM timer values (T3412(ext)=24 hours and T3324=20 s in the example) suitable to the host application.
AT+CPSMS?	+CPSMS:1,,,"00111000","00001010" OK	Read +CPSMS settings to see deep-sleep is enabled (<mode>=1) and the 3GPP PSM feature is requested at each NW registration with selected timer values.
AT+CEREG=4	OK	Enable the +CEREG extended syntax to report NW registration and PSM feature negotiation status. Note this setting is volatile.
<wait_for_NW_registration>		During successful network registration PSM feature negotiation is performed. Read the <stat> and <Assigned_Active_Time> parameters in the +CEREG AT command response and the <mode> and <Assigned_Active_Time> parameters in the +UCPSMS AT command response to check which of the following 3 cases applies.
	+CSCON: 1 +CEREG: 1,"1","0","1",7,,,"00001010","00111001"	Case 1: • the UE successfully registers to network, • the PSM feature is granted (T3324 assigned).
AT+CEREG? AT+UCPSMS?	+CEREG: 4,1,"1","0","1",7,,,"00001010","00111001" OK +UCPSMS: 1,,,"00111001","00001010",1 OK	Check the assigned PSM timer values displayed both in +CEREG and +UCPSMS AT command response: in this example T3324=20 s and T3412(ext)=25h. As it can be seen from +UCPSMS <Assigned_Periodic_TAU_Format_Type>, in this example T3412(ext) timer value comes with extended duration, thus it is displayed both by +CEREG and +UCPSMS.
	+CSCON: 1 +CEREG: 1,"1","0","1",7,,,,	Case 2: • the UE successfully registers to network, • the PSM feature is not granted (T3324 not assigned).
AT+CEREG? AT+UCPSMS?	+CEREG: 4,1,"1","0","1",7,,,, OK +UCPSMS: 0,,,"01001001",,0 OK	Check the assigned T3412 timer value: in this example T3412=54 min. As it can be seen from +UCPSMS <Assigned_Periodic_TAU_Format_Type>, in this example T3412 timer value comes with legacy duration, thus it is only displayed by +UCPSMS.
	+CEREG: 0	Case 3: • the UE does not successfully register to network, • the PSM feature can not be granted.
AT+CEREG? AT+UCPSMS?	+CEREG: 4,0 OK +UCPSMS: 0 OK	
<wait_for_RRC_connection_release>		The example continues assuming Case 1 has been observed.
	+CSCON: 0	Monitor the +CSCON URC to get the time instant the NW releases an existing RRC connection and both T3324 and T3412 timers start running. T3324 and T3412 timers are set with the NW-assigned values which may be different from the UE-requested values.

Command	Response	Description
	+UUPSMR: 1,1 or +UUPSMR: 2,3 +UUPSMR: 1,1	Monitor the +UUPSMR URC or any other deep-sleep indication described in section 8.1.3 to see when the UE entes deep-sleep. After T3324 expiry, the UE may enter PSM deep-sleep directly or with a delay (+UUPSMR <state>=2). In the latest case the UE enters deep-sleep as soon as it has completed any pending activity or deep-sleep temporary prevention (+UPSMVER <temp_dis>) is switched-off, if set.
	+UUPSMR: 0	Monitor the +UUPSMR URC or any other deep-sleep indication described in section 8.1.3 to see when the UE exits deep-sleep. The UE may exit PSM deep-sleep by itself, e.g. at T3412 expiry to perform a TAU. The PSM deep-sleep mode exit can be also anticipated by the host application through an early wake-up via the PWR_ON pin if needed.
ATD*99***1#	CONNECT	After deep-sleep exit, locally restore PPP mode if needed. IP address will be the same assigned during attach, and uplink data can be sent to the network without the need to re-register.

8.3 Extended Discontinuous Reception (eDRX)

SARA-R4 series modules support the 3GPP Release 13 feature Extended Discontinuous Reception (eDRX). When using eDRX, the UE listens to paging only periodically, without losing any paging indication, to save power. Paging is listened to only during short time periods called paging time windows (PTW), and ignored the rest of time. There is one PTW per eDRX cycle. The application can enable eDRX feature negotiation via the +CEDRXS AT command. The command also allows configuration of eDRX parameters: the requested eDRX cycle duration, also called TeDRX, and the PTW duration. If the network grants eDRX usage the assigned and finally used eDRX values can be read via +CEDRXP URC and +CEDRXRDP AT command.

eDRX is encouraged in applications where MT traffic is considered in the application design and a MT data delivery delay is affordable. It is suggested to deliver MT data with a pull mechanism already described for PSM. As a rule of thumb, eDRX is preferred to PSM when the maximum admissible MT data delay is shorter than the network T3412 duration, which has a default value of 54 minutes. In this case, to minimize power consumption, it is suggested to set the requested TeDRX cycle duration equal to the maximum affordable MT data delivery delay, and to set the requested PTW to the minimum duration, which makes paging reception reliable. If the network uses idle mode discontinuous reception (DRX), which can be checked out via the AT+UCGED=2 AT command, for paging reliability, it is advisable to request an at least two DRX cycles long PTW. Customers are advised to test out both TeDRX and PTW parameters to come to a value that best fits their use case and requirements in terms of power consumption, MT data delay and reliability.

eDRX can be also used along with the PSM feature. In this case eDRX is used while the T3324 timer is running. When the UE tries to negotiate both PSM and eDRX features, the network interprets the request as following; if the requested TeDRX and T3412 extended values have similar durations then the network interprets that the UE would like to use eDRX or PSM, if the requested TeDRX cycle is at least one order of magnitude smaller than the requested T3412 extended value then the network interprets that the UE would like to use eDRX during the T3324 active time. In the second case, for paging reliability, it is also advisable to request at least two TeDRX cycles during the T3324 active time, as shown in Figure 4: the paging occasions are listened to during the eDRX PTW according to the network configured DRX cycle. eDRX is used during the PSM T3324 active time period.

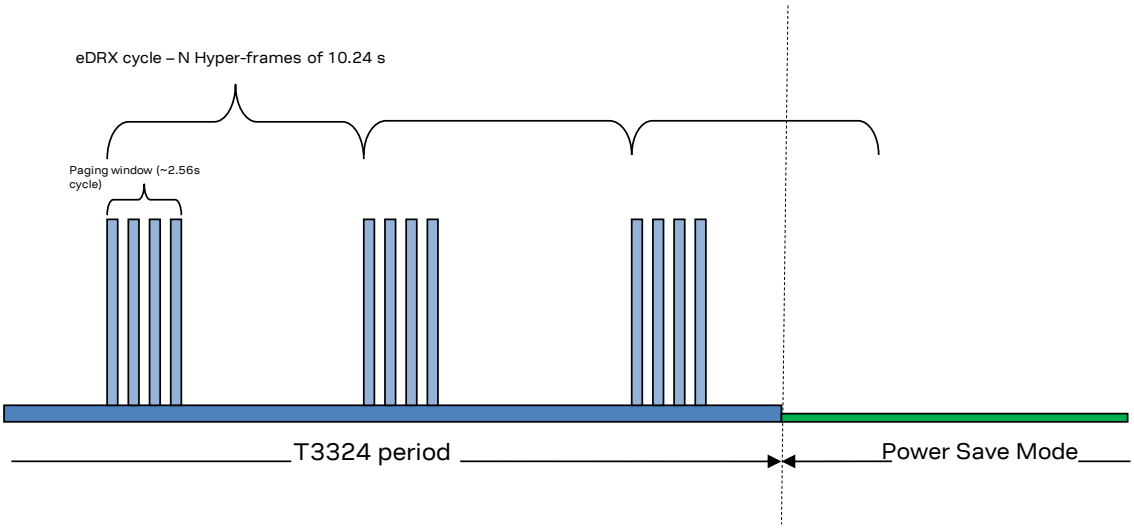

Figure 4: Paging listening when DRX, eDRX and PSM are enabled.

8.3.1.1 Encoding of timer TeDRX

The TeDRX length, i.e. the requested eDRX cycle duration, is encoded as per Table 10.5.5.32/3GPP TS 24.008 [12]:

0 0 0 0	5.12 seconds
0 0 0 1	10.24 seconds
0 0 1 0	20.48 seconds
0 0 1 1	40.96 seconds
0 1 0 0	61.44 seconds
0 1 0 1	81.92 seconds
0 1 1 0	102.4 seconds
0 1 1 1	122.88 seconds
1 0 0 0	143.36 seconds
1 0 0 1	163.84 seconds
1 0 1 0	327.68 seconds
1 0 1 1	655.36 seconds
1 1 0 0	1310.72 seconds
1 1 0 1	2621.44 seconds
1 1 1 0	5242.88 seconds
1 1 1 1	10485.76 seconds

☞ All other values shall be interpreted as 0000.

☞ In LTE Cat M1 for the eDRX cycle length duration of 5.12 s the eDRX cycle parameter 'TeDRX' is not used.

☞ The 0000 and 0001 are only applicable in LTE Cat M1. If received in NB-IoT they need to be interpreted as if eDRX has not been granted by the network.

☞ The 0100, 0110, 0111 and 1000 values are only applicable in LTE Cat M1. If received in NB-IoT they need to be interpreted as the 0010 value.

☞ The 1110 and 1111 values are only applicable in NB-IoT. If received in LTE Cat M1 they need to be interpreted as the 1101 value.

8.3.1.2 Encoding of timer PTW

The PTW length is encoded as per Table 10.5.5.32/3GPP TS 24.008 [12]:

LTE Cat-M1

0 0 0 0	1.28 s
0 0 0 1	2.56 s
0 0 1 0	3.84 s
0 0 1 1	5.12 s
0 1 0 0	6.4 s
0 1 0 1	7.68 s
0 1 1 0	8.96 s
0 1 1 1	10.24 s
1 0 0 0	11.52 s
1 0 0 1	12.8 s
1 0 1 0	14.08 s
1 0 1 1	15.36 s
1 1 0 0	16.64 s
1 1 0 1	17.92 s
1 1 1 0	19.20 s
1 1 1 1	20.48 s

NB-IoT

0 0 0 0	2.56 s
0 0 0 1	5.12 s
0 0 1 0	7.68 s
0 0 1 1	10.24 s
0 1 0 0	12.8 s
0 1 0 1	15.36 s
0 1 1 0	17.92 s
0 1 1 1	20.48 s
1 0 0 0	23.04 s
1 0 0 1	25.6 s
1 0 1 0	28.16 s
1 0 1 1	30.72 s
1 1 0 0	33.28 s
1 1 0 1	35.84 s
1 1 1 0	38.4 s
1 1 1 1	40.96 s

8.3.2 eDRX deep-sleep and paging only image

When the eDRX feature is supported by the network, it is possible for the module to further minimize its power consumption by entering deep-sleep mode when not listening to paging, i.e. when not in the PTW periods. This feature can be enabled as usual with `AT+CPSMS=1` command, after having selected eDRX deep-sleep option with `AT+UPSMVER=8` command, which forces eDRX to be used standalone, disabling PSM requests to the network.

When the eDRX deep-sleep feature is used, power consumption can be further minimized by using a low power module FW called POI (Paging Only Image) loaded during periodic PTW periods. POI loading is enabled by default and can be disabled with the `AT+UPSMVER=8,0` AT command. When POI is loaded, the module is unresponsive until it changes status by itself, due to deep-sleep mode exit at periodic TAU, paging reception or early wake-up (which is effective only once the module has entered the deep-sleep state after the PTW period). Transitions between eDRX deep-sleep mode and POI can be monitored via the RXD or DSR UART lines, which become high during POI period, whereas the module status indication GPIO, V_INT RXD levels (see section 8.1.3) do not change with respect to eDRX deep-sleep state. Usage of POI in eDRX is notified with `+UUPSMR: 1,2` URC when entering eDRX deep-sleep mode from normal operation.

8.3.3 Functional diagram of eDRX and PSM

For sake of clarity, Figure 5 illustrates the states transitions and device activity when both PSM and eDRX are active. Some configurable parameters are highlighted in the figure. In this case the negotiated eDRX cycle duration is TeDRX=10.24 s. During the PTW, the module listens to paging continuously or discontinuously in case the network uses discontinuous reception. In below example the network uses discontinuous reception with a discontinuous reception cycle TDRX=2.56 s. It should be noticed that unlike PSM related timers, eDRX and DRX related ones start instant does not depend on any previous RRC connection release. The negotiated T3324 and T3412 timers are also highlighted: eDRX is used during the T3324 active time.

1. The device is in PSM deep-sleep state, not responsive to AT commands nor paging messages. It has already registered at startup, negotiating PSM timers.
2. PSM is exited at early wake-up triggered by the host application or at T3412 timeout.
3. In case of an early wake-up the host application is expected to start a MO transmission. If a T3412 timeout occurs, the device sends a TAU keepalive message, performing a new PSM and eDRX negotiation. The device re-connects to the network.
4. Once the data or control packet transmission or reception is complete, the RRC connection is released by the network. The device enters the idle state and starts T3324 and T3412 timers.
5. While the T3324 timer is running, paging is listened to as per eDRX and DRX configuration.
6. PSM is entered after T3324 has elapsed. Operations continue as per point 1.

If after point 2 the device does not enter RRC connected state, the device will eventually re-enter PSM state as if it had not awakened from it.

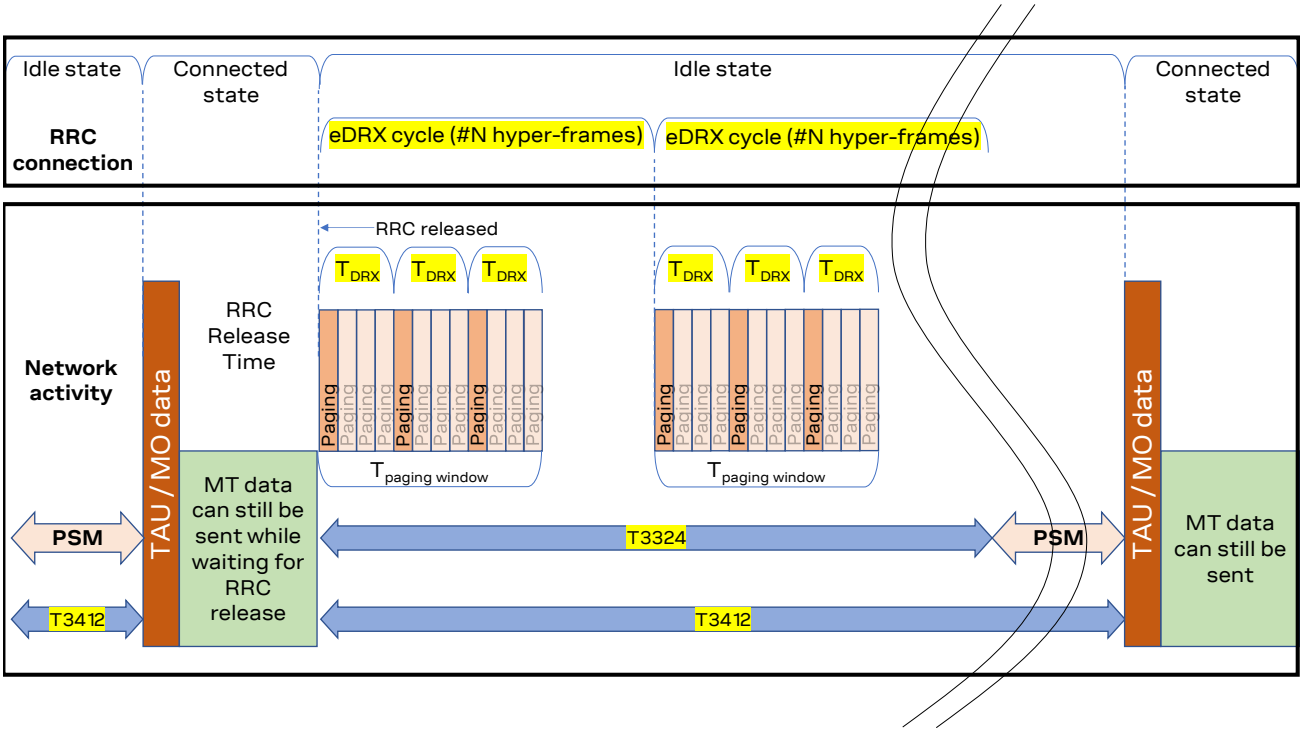

Figure 5: State transitions and module activity when both PSM and eDRX are enabled

8.3.4 Example of eDRX configuration

This example illustrates how the 3GPP eDRX feature, disabled by default, can be configured and how to check NW assigned settings.

Command	Response	Description
`AT+CLCK="SC",2`	`+CLCK: 0` `OK`	Verify if SIM PIN check is disabled, if not, disable it.

`AT+CPSMS?`	`+CPSMS: 0,,,`
	`"01100000","00000000"`
	`OK`
		Verify if PSM is disabled, if not, disable it.

`AT+UPSMVER?`	`+UPSMVER:4,3,3,4,0` `OK`	Verify if the +UPSMVER AT command is set to its default value, if not, select it.
`AT+CSCON=1` `AT+UPSMR=1`	`OK` `OK`	Enable +CSCON and +UUPSMR URCs.

`AT+CFUN=0`
`AT+CEDRXS=2,4,`
`"0111","0111"`
`AT+CFUN=15`
	`OK`
	`OK`
	
	`OK`
		Enable the 3GPP eDRX feature requests. Set eDRX timer values (TeDRX=~2min, PTW=~10s in the example) suitable to the host application.

`AT+CEDRXS=2,4`	`OK`	Enable the volatile +CEDRXP URC to report negotiated eDRX timer values.
`AT+CEREG=4`	`OK`	Enable the volatile +CEREG URC to report NW registration status.

Command	Response	Description
<wait_for_NW_registration>		During successful network registration eDRX feature negotiation is performed. The example continues assuming the UE successfully registers to the NW and the eDRX feature is granted (TeDRX and PTW assigned).
	+CSCON: 1 +CEDRXP: 4,"0111","0111","0011" +CEREG: 1,"1","0","1",7,,,,	Check the assigned and finally used eDRX timer values, if any, displayed both in +CEDRXP URC and and +CEDRXRDP AT command response: in this example (TeDRX=~2min and PTW=~5s in this case). Also check the +UCPSMS response to get the assigned T3412 timer.
AT+CEDRXRDP AT+CEREG? AT+UCPSMS?	+CEDRXRDP: 4,"0111","1010","0111" +CEREG: 4,1,"1","0","1",7,,,, OK +UCPSMS: 0,,,"01001001",,0 OK	
	+CSCON: 0	Monitor the +CSCON URC to get the time instant the NW releases an existing RRC connection and the eDRX feature starts being used.
AT+CFUN=0 AT+CPSMS=1 AT+UPSMVER=8,0 AT+CFUN=15		Enable eDRX deep-sleep for additional power savings. Monitor the +UUPSMR URC or any other deep-sleep indication described in section 8.1.3 to see when the UE enters and exits deep-sleep.
AT+CFUN=0 AT+UPSMVER=8,3 AT+CFUN=15		Enable eDRX deep-sleep with POI loading during PTW to further increase power savings. Monitor POI loading using in any of the ways described in section 8.3.2.
ATD*99***1#	CONNECT	After deep-sleep exit, locally restore PPP mode if needed. IP address will be the same assigned during attach, and uplink data can be sent to the network without the need to re-register.

9 Monitoring module status

9.1 Retrieve and interpret diagnostic information

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

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

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

Some AT commands provide a choice on how to handle the URCs when the AT interface is busy; for all other AT commands, URC is issued at the return into command mode, as explained in SARA-R4 series AT command manual [2], in the “URCs presentation deferring” section.

URCs and AT command responses are presented with their generic syntax as parameters names are explanatory. For their precise meanings, see the SARA-R4 series AT command manual [2].

9.1.1 Diagnostic information via URCs

Command	URC	Description	Can be polled
AT+CSCON=1	+CSCON: 1	Return the status of the RRC connection (idle or connected). Persistent setting.	Yes
AT+CREG=3	+CREG: <stat>[,[<lac>],[<ci>][,[<AcTStatus>][,<cause_type>,<reject_cause>]]]	Enable registration status URC for non-EPS services (for example, SMS) and reject cause in case of unavailability of such services.	Yes
AT+CEREG=5	+CEREG: <stat>[,[<tac>],[<ci>],[<AcT>][,[<cause_type>],[<reject_cause>][,[<Assigned_Active_Time>,[<Assigned_Periodic_TAU>]]]]]	Enable registration status URC for EPS services, reject cause in case of unavailability of such services and PSM related timers if granted by the network.	Yes
AT+CGREG=2	+CGREG: <stat>[,<lac>,<ci>[,<AcT>,<rac>]]	Enable registration status URC for PS services in 2G networks.	Yes
AT+CGEREP=2,1	+CGEV: NW PDN DEACT <cid>	Report all registration and PDN connectivity status events. The first parameter of the AT command is set to 2 indicate that URC will not be discarded in case the AT interface is busy.	No
AT+CTZR=1	+CTZV: <tz>	Enable reporting of changes in time zone. Usually, time zone information is provided by the network at LTE attach only.	No
AT+CMER=1,0,0,2,1	+CIEV: <descr>,<value>	Report variations in some indicators like roaming, SIM indication (provided that the feature is configured via +UGPIOC), signal level.	No
AT+CNMI=2,1	+CMTI: <mem>,<index>	Report the index in current selected memory (can be the factory-programmed setting ME or SIM, see +CPSM read command) where the mobile terminated SMS has been stored. The first parameter set to 2 indicates that URC are buffered in case of busy AT interface. The setting is volatile and shall be re-entered at every switch on or exit from PSM.	No
AT+USIMSTAT=7	+UUSIMSTAT: <state>	Report SIM initialization progress, SIM phonebook initialization progress, and SIM REFRESH events (each group of URCs can be singularly disabled). SIM Refresh URC might indicate the change of some operational parameters in the UICC card (for example, IMSI swap, SIM profile installation after remote SIM provisioning). The setting is persistent.	No
AT+UBIP=1	+UUBIP: <ev_cmd>,<val>	URC are raised when Open Channel, Close Channel, Send Data, Receive Data and Channel status events are issued by the SIM card towards the device to handle a SIM OTA session, for example for remote SIM provisioning. The embedded BIP client will cater for establishing the required socket and exchange data with the SIM OTA server. The setting is persistent.	No
AT+UFOTASTAT=1	+UFOTASTAT: <event>,<param1>[,<param2>]	Provide information on the progress and outcome of the Firmware download over the air via LwM2M (uFOTA). The setting is persistent.	No
AT+ULWM2MSTAT=1	+ULWM2MSTAT: <event>,<param1>[,<param2>]	Enable URC to report the activity of the embedded LwM2M client. The setting is persistent.	No

Command	URC	Description	Can be polled
AT+CEINFO=1	+CEINFO: <reporting>,<CE_enabled>,<UE_state>,<downlink_repetition_factor>,<uplink_repetition_factor>,<RSRP_value>,<CINR>	Volatile setting, it reports variation of the Coverage extension mode and related transmission parameters (for example, repetitions schemes to be used) detected by the device or assigned by the network.	Yes
AT+CEDRXS=1	+CEDRXP: <AcT_type>[,<Requested_eDRX_cycle>[,<Assigned_eDRX_cycle>[,<Assigned_paging_time_window>]]]	If eDRX is used by the host application, the URC can report changes in eDRX settings imposed by the network in different areas or times. The setting is persistent.	Yes

☞ Always consider to apply the +CGEREP AT command with <mode> equal 2, for example AT+CGEREP=2, in order to avoid to lose URCs when the AT interface is busy in executing some other AT commands.

9.1.2 Diagnostic information via polling

Command	Response (omitting OK)	Description	Suggested usage
ATI ATI9	SARA-R422M8S-00B-00 00.12,A00.00	Return the model and FW identification, useful for tracking purposes.	Module initialization
AT+CGSN	355438110017558	Return the IMEI.	Module initialization
AT+CIMI AT+CCID	001010123456789 +CCID: 89860000502000180722	Return the SIM identities for tracking purposes. They can change after a SIM refresh event that can be reported by +UUSIMSTAT URC.	Module initialization
AT+UBANDMASK?	+UBANDMASK: 0,185079967,2,1,134748319,1048642,2,2621824	Return band mask selection.	Module initialization
AT+UMNOPROF?	+UMNOPROF: 90	Return MNO profile set.	Module initialization
AT+UCGED?	+UCGED: 2 6,<svc>,<MCC>,<MNC><EARFCN>,<Lband>,<ul_BW>,<dl_BW>,<TAC>,<LcellId>,<P-CID>,<mTmsi>,<mmeGrId>,<mmeCode>,<RSRP>,<RSRQ>,<Lsinr>,<Lrrc>,<RI>,<CQI>,<avg_rsrp>,<totalPuschPwr>,<avgPucchPwr>,<drx>,<l2w>,<volte_mode>[,<meas_gap>,<tti_bundling>	Return several cell parameters as measured by the module or provided by the network. Some values like CQI and signal indicators are periodically refreshed in the module on a 0.5 s base, so the application should average them.	Low periodicity
AT+CESQ?	+CESQ:,,,,<rsrq>,<rsrp>	Return signal quality and level, and it is more precise than +CSQ. It is subjected to transitions due to local reset of values at changes in RRC state (idle, connected) so the host application should average the values.	Periodically (for example, every 50 to 10 s)
AT+COPS?	+COPS: <mode>[,<format>,<oper>[,<AcT>]]	It returns the current registered PLMN in the configured format, RAT is fixed to 7 (LTE, Cat-M1).	Periodically (30 s) and when detecting problems

Command	Response (omitting OK)	Description	Suggested usage
AT+CGATT?	+CGATT: 0	As AT+COPS?, it returns 0 when the module enters in out of coverage conditions, despite no PS detach has occurred and PS services are just suspended.	Periodically (20 s) and when detecting problems
AT+CGDCONT?	+CGDCONT: <cid>,<PDP_type>,<APN>,<PDP_addr>,<d_comp>,<h_comp>[,<IPv4AddrAlloc>,<request_type>,<P-CSCF_discovery>,<IM_CN_Signalling_Flag_Ind>[,<NSLPI>[,<secure_PCO>[,<IPv4_MTU_discovery>[,<Local_Addr_Ind>]]]]]	It returns the active and defined EPS bearers with the APN used and the IP type and addresses.	Periodically (30 s) and when detecting problems
AT+CPOL?	+CPOL: <index1>,<format>,<oper1>[,<GSM_AcT1>,<GSM_Compact_AcT1>,<UTRAN_AcT1>[,<E-UTRAN_AcT>]]	It returns the high priority PLMN list, which might change at SIM refresh.	Module initialization and SIM refresh, only in debug/test mode
AT+CEDRXRDP	+CEDRXRDP: <AcT_type>[,<Requested_eDRX_cycle>,<Assigned_eDRX_cycle_value>,<Assigned_paging_time_window>]	It returns the current eDRX parameters assigned by the mobile network.	If eDRX is used, the host should monitor CTS line to avoid waking up the module during eDRX/sleep periods
AT+CPSMS?	+CPSMS: <mode>,[<Requested_Periodic_RAU>],[<Requested_GPRS_READY_timer>],[<Requested_Periodic_TAU>],[<Requested_Active_Time>]	It returns the PSM settings as required to the network. As setting is persistent, if the network does not grant PSM, the module will propose the PSM timers at every attach and registration attempt.	Module initialization
AT+UCPSMS?	+UCPSMS: <mode>,[<Assigned_Periodic_RAU>],[<Assigned_GPRS_READY_timer>],[<Assigned_Periodic_TAU>],[<Assigned_Active_Time>],[<Assigned_Periodic_TAU_Format_Type>]	It returns the PSM settings as assigned by the network. If PSM timers are not reported by +CEREG, this command can be periodically polled. Periodic TAU timer is also reported.	At change of registration information (as reported by +CEREG)

☞ To check the detected radio signal strength and quality, see the +CESQ AT command for LTE networks (Cat M1 and NB-IoT), and the +CSQ AT command for 2G networks (GSM/EGPRS).

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

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

When a problem at a specific level is encountered, the countermeasure for that level should be tried and, if not resolving the issue, proceed with the solutions for the lower levels. Table 14 shows a full-stack watchdog for monitoring SARA-R4 series modules.

Level	Problem	Countermeasure	AT commands / actions	Notes
Socket/dial-up	Cannot send/receive data	Close and re-open socket	AT+USOCL=<socket_id> AT+USOCR=<protocol> AT+USOCO=…	
		Disconnect and re-connect dial-up	Send +++ / Move DTR ATD*99***<cid>#	
IP/PDP	Cannot get an IP address; cannot establish dial-up	Detach/re-attach	AT+CFUN=0 AT+CFUN=1	Consider restrictions to multiple <cid>s active for APN. If IPv6-only PDN is set in Verizon Wireless MNO setting, detach/deactivation may be caused by failing IPv6 acquire by SLAAC. The retry is managed automatically based on VZW DR logic. Automatic deactivation does not apply if UL data is disabled via +UMNOPROF: 9,0.
		Deactivate/re-activate context (<cid> != 1)	AT+CGACT=0,<cid> AT+CGACT=1,<cid>	
Network registration	Cannot register	Detach/re-attach	AT+CFUN=0 AT+CFUN=1	Preferably use AT+CFUN=0/1 for registration cycles. AT+CFUN=0/1 is faster than AT+COPS=2/0.
RF	Cannot register	Disable/re-enable RF functionality	AT+CFUN=0 AT+CFUN=1	AT+CFUN=4 is NVM persistent, better to use AT+CFUN=0.
Module FW	Cannot register	Soft reset	AT+CFUN=15	
AT interface	No response from module	HW switch off	GPIO power control	For details and alternatives, see the SARA-R4 series system integration manual [3].

Table 14: Full-stack watchdog for SARA-R4 series modules

10 SIM

10.1 SIM communication

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

- commands for restricted access
- commands for generic access

10.1.1 Commands for restricted access

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

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

10.1.1.1 Examples of UICC communication

Below are examples of commands for restricted access.

Command	Response	Description
Read IMSI(International Mobile Subscriber Identity)		
AT+CRSM=176,28423,0,0,0	+CRSM: 144,0,"082922107840836055" OK	Read the IMSI. 176 is the read command for EF in binary format. 28423 is the ID for EF_IMSI, the SIM elementary file where IMSI is stored by SIM manufacturer. The <response> parameter in +CRSM answer contains few prefix bytes followed by the IMSI value with swapped nibbles.
AT+CIMI	222018704380655 OK	Read the IMSI. The response is the readable serial number. This example is for reference only, as an alternative AT command to read IMSI.
LOCI management		
AT+CRSM=176,28542,0,0,0	+CRSM: 144,0,"623C50A322F210D5BD0000" OK	Read EF_LOCI, the SIM elementary file where information about last CS location is stored
AT+CRSM=214,28542,0,0,11,"FFFFFFFFFFFFFFFFFFFFFF"	+CRSM: 144,0,"" OK	Erase EF_LOCI content. This command is useful to start a registration procedure from scratch. For this purpose, erase the below EF too: • EF_PSLOCI (28531) • EF_EPSLOCI (28643)
Read emergency call Codes		
AT+CRSM=178,28599,1,4,0	+CRSM: 144,0,"11F2FFFFFFFFFFFFFFFFFFFF

Command	Response	Description
	OK	

10.1.2 Commands for generic access

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

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

10.1.3 SIM logical channels

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

10.1.3.1 Basic logical channel

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

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

10.1.3.2 Supplementary logical channels

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

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

In SARA-R4 modules, in addition to logical channels 0, the module automatically activates logical channel 1, which can be use by the host application. Since some SIM applications (e.g., ISD-R) cannot have multiple sessions, they should be selected on the channel intended for them and in these cases the usage of logical channel 1 could be mandatory.

Command	Response	Description
Generic SIM access		
AT+CSIM=10,"0070000000"	+CSIM: 6,"029000" OK	Open a new supplementary logical channel. As per ISO/IEC 7816-4, <response> parameter contains • the number assigned to the opened channel: “02”. (i.e., channel “01” is already active) • the action result: “9000” (‘Command successfully executed’)
AT+CSIM=10,"0170800200"	+CSIM: 4,"9000" OK	Close the supplementary channel 2 (indicated in the 4th byte), using supplementary ch1 (indicated in the 1st byte). SARA-R4 allows commands for supplementary channel closure only if received on channel 0 or 1.

10.2 Chip SIM

For devices using a soldered-down chip SIM, consider what network or networks the device will connect to. Furthermore, consider the need to connect to a test network or base station simulator call-boxes, which may require a specific UICC profile. Anticipate such needs and configure a profile to connect to such networks or simulators.

Below are some alternatives for testing purposes:

- Configure a device with a SIM card holder for physical removable SIM for such engineering or pre-production activities.
- Disable authentication and integrity checks on the tester side by proper setting, and on the module by using the `AT+UDCONF=81,0` AT command. For more details, see SARA-R4 series AT commands manual [2].

11 SMS

11.1 Preferred message storage

The factory-programmed value for SARA-R4 series modules is "ME" for the three memory parameters <mem1>, <mem2> and <mem3>. The setting can be set or read by the +CPMS AT command.

The example below sets all memory parameters to “ME” by the +CPMS AT command.

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.

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

11.2 SMS handling and access technology

All SARA-R4 MNO profiles use combined attach (CS & PS). If successful, both data and SMS services are allowed. If LTE attach is successful for EPS only services, SMS can still be supported (the “SMS only” case). If LTE attach is not successful for SMS, the module can try registration on a different RAT, e.g., 2G. Accordingly, the SMS support could be related to the selected access technology.

If AT+URAT=8 is applied, the attach becomes “EPS only” (with "SMS only" additional update type included). In this case, even if SMS services are accepted, the +CREG read command and URC would report that it is not registered for CS services.

Since it is possible that SMS services are not supported in NB-IoT, in AT+URAT=8 there is no means to understand this other trying to send out an SMS. In addition, because the network is not including SMS only flag in the attach accept message, the module will repeat tracking area update (TAU) about every 10 s, causing high power consumption. In summary:

1. In mono-RAT (NB-IoT), i.e. AT+URAT=8, registered on a network without SMS support:
   - TAU procedures every 10 s for maximum 5 times every 12 minutes (around 25 times per hour).
   - Pay attention to power consumption.
2. In multi-RAT (NB-IoT plus LTE Cat M1 and/or 2G), e.g. AT+URAT=7,8,9, registered on a network without SMS support:
   - Standard TAU procedures.
   - longer network scans (the NB-IoT is the RAT with longest scans).
   - this configuration could be considered as a possible trade-off.
3. In multi-RAT (NB-IoT plus LTE Cat M1 and/or 2G), e.g. AT+URAT=7,8,9 registered on a network with SMS support:
   - +CREG indication is reliable in 2G RAT.
   - +CREG indication is not reliable in LTE Cat M1/NB-IoT, accordingly try to send a SMS.
   - +CSCON indication reports information about the radio connection status.

In conclusion, working in a multi-RAT configuration is recommended, and considered as a possible workaround to the scenarios described above in point 1 and 2.

11.3 SMS auto-ACK

It is possible to configure manual acknowledgement of MT SMS (RP-ACK) via AT+CSMS=1, AT+CNMI=1,2 and AT+CNMA commands. To fully enable this feature, the LwM2M client must be disabled by issuing

the `AT+ULWM2M=1` command. Note that the setting is persistent across power cycles and that the disabling of the LwM2M client will prevent uFOTA feature.

12 EFS backup & restore

Due to the nature of Flash memory, the Embedded File System (EFS) may incur memory corruption if the safe & graceful shutdown procedure outlined in the 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 information.

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

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

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

⚠ It is critical that the host application follows the proper safe & graceful shutdown procedure outlined in the SARA-R4 series system integration manual [3]. Backup & restore feature is intended only as an additional backup mechanism if, on the potential rare occasion, the host application shutdown is not conforming to the graceful power down guidelines.

12.1 Description

There are two parts to the EFS backup & restore feature for SARA-R4 series modules.

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. The procedure could include security data, e.g. certificates.

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

There are three types of non-fatal corruptions:

- Lost of IMEI
- MNO profiles lost or duplicated
- Device goes into the non-signaling mode (for more details, see the Production and validation test app note listed in Table 1)

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

☞ Personalization data for security, calibrations and unique data will be restored. User files, parameters and profiles will be handled by the backup and restore process differently, based on the SARA-R42 product series implementations, as shown in the Table 15.

Item	SARA-R42 "00B" product version	SARA-R42 "01B" product version
Personalization data for security, calibrations, and unique data	Restored.	Restored.
Files in user file system	Not considered by the backup and restore process.	Not considered by the backup and restore process.

Item	SARA-R42 “00B” product version	SARA-R42 “01B” product version
MNO profiles	Back to the factory programmed settings (i.e. MNO profile 90 “Global” as default). After backup & restore process, select desired MNO profile with +UMNOPROF.	Restored, if previously backed-up.
User NVM settings (i.e. +UBANDMASK)	Back to the factory programmed settings.	Restored, if previously backed-up.
User certificate and private keys	Back to the factory programmed settings if any.	Restored, if previously backed-up.

Table 15: Backup & restore feature implementation in SARA-R42 “00B” and “01B” product versions.

12.1.1 EFS backup

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

Optionally, the host can issue backup on an infrequent and rare basis according to the demand. This could be when some significant information in the file system has been modified via AT commands. For example, information regarding the personalization data for security. One scenario is after the host application factory initial "production", which may include the module configuration of a specific use case requirement related to the security functionalities. Creating a backup in this “production” scenario is likely safe, as long as the production is handing the module in a safe manner that does not expose risk to memory corruption before performing the backup. The backup command can also provide some information about the last backup.

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

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

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

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

To detect that the backup function is completed, and the AT interface is available:

- Wait for `+UUBKUPDATA` URC
  - Example URC of a successful backup: `+UUBKUPDATA: 1,1`

12.1.2 EFS restore

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

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

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

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

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

☞ Upon receiving the +UUBKUPDATA: 2,1 URC, a reboot is automatically performed by the module.

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

- Lost of IMEI, which can be detected with the +CGSN AT command, where:
  - +CSGN returns the "+CME ERROR: memory failure" error result code
- MNO profiles lost or duplicated, which can be detected with +UMNOPROF AT command
- The device goes into the non-signaling mode and is unable to exit with AT+UTEST=0, and +CFUN cannot change its state from a value of 5. This non-signaling state can be checked with the +CFUN read command, where the device would return a value of 5.

Restore is only intended for the above situations.

Example of +CGSN AT command to detect lost IMEI

Command	Response	Description
AT+CGSN	+CME ERROR: memory failure	Error result code indicates lost IMEI using +CGSN AT command.

To detect it the module boot-up is complete and AT interface is available after a possible restore:

- Loop AT, e.g., every one second, until the "OK" final result code is received.
- Enable and monitor the GPIO pins with “Module status indication” function by 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.

12.1.3 Creating backup after flashing FW update with delta package

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

12.1.4 EasyFlash, backup and SMS storage

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

- Define a new EFS backup through the +UBKUPDATA AT command.
- Set the preferred SMS message storage, if different from the factory-programmed setting, with +CPMS AT command just once after flashing. This step is required if the host application use SMS, otherwise this step can be ignored.

12.1.5 Secure storage backup & restore

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

To monitor the secure storage corruption, use the following AT commands:

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

In case of secure storage corruption, execute the following AT commands:

Command	Response	Description
AT+USECOPCMD="rotrestore",1	OK	Restore the secure storage.

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

13 Restore factory configuration

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

☞ Profiles can be restored with the ATZ command.

☞ AT commands factory-programmed values stored in NVM and profiles are listed in appendix B.2 of SARA-R4 series AT commands manual [2].

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

Restoring the factory configuration takes 2 steps:

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

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

Table 16 shows some examples.

Command	Response	Description
Delete all user files previously saved with USER flag in the file system		
AT+UFACTORY=1,0	OK	Set +UFACTORY to delete all user files previously stored with USER flag in the file system. No restore is performed so far.
AT+UFACTORY?	+UFACTORY: 1,0 OK	Check the restore action currently set.
AT+CFUN=16	OK	Reboot the module. At next reboot, the restore action previously set is applied.
Delete all modem profiles in NVM		
AT+UFACTORY=0,1	OK	Set +UFACTORY to delete all modem profiles. In detail: native modem profiles are reset, while added modem profiles are deleted. No restore is performed so far.
AT+UFACTORY?	+UFACTORY: 0,1 OK	Check the restore action currently set.
AT+CFUN=16	OK	Reboot the module. At next reboot, modem profiles are reverted to the factory programmed values.
Restore UART and UPSV settings to default in NVM		
AT+UFACTORY=0,2	OK	Set +UFACTORY to restore UART and +UPSV settings to default in NVM. No restore is performed so far.
AT+UFACTORY?	+UFACTORY: 0,2 OK	Check the restore action currently set.
AT+CFUN=16	OK	Reboot the module. At next reboot, UART and +UPSV settings are reverted to the factory programmed values.
Cancel a delete operation (before reboot)		

Command	Response	Description
AT+UFACTORY=1,0	OK	Set a +UFACTORY action.
AT+UFACTORY?	+UFACTORY: 1,0 OK	Check the action currently set. Now, a user files deletion is requested and will be applied at next reboot.
AT+UFACTORY=0,0	OK	Cancel any delete action.
AT+UFACTORY?	+UFACTORY: 0,0 OK	No delete action will be applied at next reboot.

Table 16: +UFACTORY AT command examples

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

14 u-blox services handling

SARA-R42 series modules are built with some u-blox services, i.e. internal IP applications, e.g., LwM2M client, security services, etc.. User side tuning could be needed to properly interact with the u-blox services.

For more details about u-blox services, see the documents listed in the Table 1.

14.1 Interaction with private networks

When a SARA-R42 series module is located inside a private network, e.g. a network with a private APN and its specific firewall rules, some configurations could be needed to properly manage the u-blox services.

The scenarios below are possible when a SARA-R42 series module is located in a private network:

1. The user is interested in u-blox services:
   - the private network must be properly set, e.g., routing tables, permissions, etc., so that the module can reach the u-blox reference servers for the running services (LwM2M, security, etc.)
2. The user is not interested in u-blox services:
   - clients of u-blox services which are not in scope shall be properly and explicitly disabled:
     - To disable LwM2M service: apply `AT+ULWM2M=1` then `AT+CFUN=16` (module reboot for saving NVM settings). For more details, see LwM2M objects and commands application note [9].
     - To disable security service: apply `AT+USECMODE=0` then `AT+CFUN=16` (module reboot for saving NVM settings). This AT commands sequence could be issued if the SARA-R42 module is still in the `+USECDEVINFO: 1,0,1` status and the security sealing has not been already performed. For more details, see the IoT Security-as-a-Service overview [6].

15 Migration guide from SARA-R410M / SARA-R412M and hints

Below is a list of software changes between SARA-R410M / SARA-R412M and SARA-R422 / SARA-R422S / SARA-R422M8S / SARA-R422M10S modules with a brief description, which could help in migrating a host application between the two modules. For detailed explanation of the AT commands mentioned, see the SARA-R4 series AT commands manual [2].

Command or feature	SARA-R422 / SARA-R422S / SARA-R422M8S / SARA-R422M10S	SARA-R412M-02B-03 SARA-R412M-02B-04	SARA-R410M-63B / SARA-R410M-73B / SARA-R410M-83B	SARA-R410M-02B-03 SARA-R410M-02B-04
RATs	• 3GPP Rel. 14 LTE Cat M1 • NB2 • EGPRS	• 3GPP Rel. 13 LTE Cat M1 • NB1 • EGPRS	• 3GPP Rel. 13 LTE Cat M1 • NB1 (not supported by "63B" and "73B" product versions)	• 3GPP Rel. 13 LTE Cat M1 • NB1
Connected Mode Mobility (CMM)	Handover Intra-band & Inter-band	n.a.	Handover Intra-band	n.a.
USB enumeration	• HS-USB Diagnostics 90B2	• HS-USB Modem 90B2 • HS-USB Diagnostics 90B2 • HS-USB WWAN Adapter 90B2	• HS-USB Modem 90B2 • HS-USB Diagnostics 90B2 • HS-USB WWAN Adapter 90B2	• HS-USB Modem 90B2 • HS-USB Diagnostics 90B2 • HS-USB WWAN Adapter 90B2
AT interface	AT commands handler applies the proper line termination sequence “\r\n” to all supported AT commands.	AT commands handler applies the uncorrected line termination sequence “\n\r” in the +CSGT URC and some AT commands in test mode like “AT+UPSV=?”, “AT+UFOTA=?” plus some others related to the LWM2M functionality.	AT commands handler applies the uncorrected line termination sequence “\n\r” in the +CSGT URC and some AT commands in test mode like “AT+UPSV=?”, “AT+UFOTA=?” plus some others related to the LWM2M functionality.	AT commands handler applies the uncorrected line termination sequence “\n\r” in the +CSGT URC and some AT commands in test mode like “AT+UPSV=?”, “AT+UFOTA=?” plus some others related to the LWM2M functionality.
+USIO	Serial interfaces configuration options: • 0: AT="UART" • 1: AT="UART"; AT="AUX UART" • 4: AT="UART"; GNSS="AUX UART"[2]	n.a.	n.a.	n.a.
+UUARTCONF	Available for AUX UART configuration	n.a.	n.a.	n.a.
+CFUN (options)	0, 1, 4, 5, 15, 16, 19	0, 1, 4, 5, 15	0, 1, 4, 5, 15	0, 1, 4, 5, 15

[2] Not supported by SARA-R422

Command or feature	SARA-R422 / SARA-R422S / SARA-R422M8S / SARA-R422M10S	SARA-R412M-02B-03 SARA-R412M-02B-04	SARA-R410M-63B / SARA-R410M-73B / SARA-R410M-83B	SARA-R410M-02B-03 SARA-R410M-02B-04
+UMNOPROF	• Default MNO profile: 90 (global) • MNO profile 0 (undefined): n.a. • To restore the settings to the factory programmed values for the specific profile, the profile can be reapplied with UMNOPROF set command.	• Default MNO profile: 0 (undefined) • To restore the settings to the factory programmed values for the specific profile, the profile shall be changed via +UMNOPROF set command and set back to the current value.	• Default MNO profile: 28 (Softbank) on "63B", 39 (SKT) on "73B", 4 (Telstra) on "83B" • To restore the settings to the factory programmed values for the specific profile, the profile shall be changed via +UMNOPROF set command and set back to the current value.	• Default MNO profile: 0 (undefined) • To restore the settings to the factory programmed values for the specific profile, the profile shall be changed via +UMNOPROF set command and set back to the current value.
+UBANDMASK (options)	(0-2),18446744073709551615, 18446744073709551615	(0-1),0xffffffffffffffff,0xffffffffffffffff	(0-1),0xffffffffffffffff,0xffffffffffffffff	(0-1),0xffffffffffffffff,0xffffffffffffffff
+URAT (options)	7, 8, 9	7, 8, 9	7, 8[3]	7, 8
<AcT> support in: +COPS +CREG +CGREG	0, 3, 7, 9	0, 3, 7, 9	7, 9	7, 9
+COPS	<mode>=0 (automatic) in set functionality does not reset the selected RATs configuration	<mode>=0 (automatic) in set functionality does reset the selected RATs configuration	<mode>=0 (automatic) in set functionality does reset the selected RATs configuration	<mode>=0 (automatic) in set functionality does reset the selected RATs configuration
+CGACT	Always issue the AT+CGACT=1,<cid> command on used context <cid> even if the +CGDCONT AT command returns that the context is still active with a valid IP address. This is highly recommended to activate the PS data connection avoiding possible conflicts between applications.	Optional	Optional	Optional
+CTZU (options)	• SARA-R42 “00B” product versions default value: 0: automatic time zone via NITZ disabled	0: automatic time zone via NITZ disabled	0: automatic time zone via NITZ disabled	0: automatic time zone via NITZ disabled

[3] Not supported by SARA-R410M-63B and SARA-R410M-73B product versions

Command or feature	SARA-R422 / SARA-R422S / SARA-R422M8S / SARA-R422M10S	SARA-R412M-02B-03 SARA-R412M-02B-04	SARA-R410M-63B / SARA-R410M-73B / SARA-R410M-83B	SARA-R410M-02B-03 SARA-R410M-02B-04
	• SARA-R42 “01B” product versions default value: 1: automatic time zone via NITZ enabled			
+UHPPLMN	• SARA-R42 “00B” product versions: n.a. • SARA-R42 “01B” product versions: available for setting the periodic search for higher priority PLMN (HPPLMN)	n.a.	n.a.	n.a.
+UURCCONF	• SARA-R42 “00B” product versions: n.a. • SARA-R42 “01B” product versions: available for configuring the list of the AT terminals enabled for URC reception	n.a.	n.a.	n.a.
+UPSV (options)	0, 3, 4	0, 4	0, 4	0, 4
+UPSMVER (options)	4, 8	1, 2, 4, 8	1, 2, 4, 8	1, 2, 4, 8
+UCGED (options)	0, 2 The option 5 is considered as a redundant syntax: accordingly it has been dropped.	0, 2, 5	0, 2, 5	0, 2, 5
SMS URCs with MUX	Available	n.a.	n.a.	n.a.
ePCO disabling	+UCFGCIOT AT command	Suitable MNO profile 101	Suitable MNO profile 101 in SARA-R410M-83B only	Suitable MNO profile 101
+ULWM2M	• SARA-R42 “00B” product versions: the LwM2M client is enabled by default • SARA-R42 “01B” product versions: the LwM2M client	The LwM2M client is enabled by default.	The LwM2M client is enabled by default.	The LwM2M client is enabled by default.

Command or feature	SARA-R422 / SARA-R422S / SARA-R422M8S / SARA-R422M10S	SARA-R412M-02B-03 SARA-R412M-02B-04	SARA-R410M-63B / SARA-R410M-73B / SARA-R410M-83B	SARA-R410M-02B-03 SARA-R410M-02B-04
	is enabled by default only for the Verizon MNO profile			
+ULWM2MSTAT URC	Applied syntax (no spaces between the provided values) +ULWM2MSTAT: <event>,<param1>[,<param2>]	Applied syntax (spaces between the provided values) +ULWM2MSTAT: <event>, <param1>[, <param2>]	Applied syntax (spaces between the provided values) +ULWM2MSTAT: <event>, <param1>[, <param2>]	Applied syntax (spaces between the provided values) +ULWM2MSTAT: <event>, <param1>[, <param2>]
+UFOTASTAT URC	Applied syntax (no spaces between the provided values) +UFOTASTAT: <event>,<param1>[,<param2>]	Applied syntax (spaces between the provided values) +UFOTASTAT: <event>, <param1>[, <param2>]	Applied syntax (spaces between the provided values) +FOTASTAT: <event>, <param1>[, <param2>]	Applied syntax (spaces between the provided values) +UFOTASTAT: <event>, <param1>[, <param2>]
+UPSMR and related +UUPSMR URC	Applied syntax (no spaces between the provided values) +UUPSMR: <state>[,<param1>]	Applied syntax (spaces between the provided values) +UUPSMR: <state>[,<param1>]	Applied syntax (spaces between the provided values) +UUPSMR: <state>[,<param1>]	Applied syntax (spaces between the provided values) +UUPSMR: <state>[,<param1>]

+UBKUPDATA	• SARA-R42 “00B” product versions:
	  ○ module unique data restored
	  ○ user files, parameters and profiles (customer settings), not restored
	• SARA-R42 “01B” product versions:
	  ○ module unique data restored
	  ○ user files not restored
	  ○ MNO profiles, user NVM settings, user certificate, and private keys are restored, if previously backed-up
		• module unique data restored
		• the whole file system (customer settings too) restored
			n.a.	• module unique data restored
				• the whole file system (customer settings too) restored

+UFACTORY	available	n.a.	n.a.	n.a.
Security	available[4]	n.a.	available	n.a.
Internal GNSS	available[5]	n.a.	n.a.	n.a.

[4] Not supported by SARA-R422
[5] Not supported by SARA-R422 and SARA-R422S

Command or feature	SARA-R422 / SARA-R422S / SARA-R422M8S / SARA-R422M10S	SARA-R412M-02B-03 SARA-R412M-02B-04	SARA-R410M-63B / SARA-R410M-73B / SARA-R410M-83B	SARA-R410M-02B-03 SARA-R410M-02B-04
CellLocate®	available[5]	available	available	available

Table 17: Software migration guide from SARA-R412M and SARA-R410M

Appendix

A Glossary

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

Table 18: Abbreviations and terms

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 FW update application note, UBX-17049154
[5] u-blox Internet applications development guide application note, UBX-20032566
[6] u-blox Security-as-a-Service overview, https://developer.thingstream.io/guides/security-services
[7] u-blox SARA-R4 / SARA-R5 GNSS implementation application note, UBX-20012413
[8] u-blox Mux implementation in cellular modules application note, UBX-13001887
[9] u-blox LwM2M objects and commands application note, UBX-18068860
[10] u-blox SARA-R5 SARA-R422 AWS IoT Core_ application note, UBX-20044809
[11] u-blox EVK-R4 user guide, UBX-16029216
[12] 3GPP TS 24.008 - Mobile radio interface layer 3 specification
[13] 3GPP TS 27.010 V3.4.0 - Terminal Equipment to User Equipment (TE-UE) multiplexer protocol (Release 1999)
[14] GSMA TS.34 IoT Device Connection Efficiency Guidelines

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	Comments
R01	27-Apr-2021	fdil	Initial release
R02	09-Oct-2022	fdil	SARA-R42 “00B” IP release
R03	17-Nov-2022	fdil	Added support for SARA-R42 "01B" product versions

Contact

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