



# SARA-R5 series

## Application development guide

Application note



### Abstract

This document provides detailed technology architecture and examples of how to use AT commands with u-blox SARA-R5 series modules.

## Document information

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# 1 Introduction

This document provides guidance for developing applications that interface with the u-blox SARA-R5 series module, including examples of AT command sequences for specific use cases.

This should be the first document to read when working on an application for SARA-R5. It starts by giving a generic overview on low power wide area network (LPWAN ) technology in section 2. Then, it describes the basic application design steps which should be followed when integrating the SARA-R5 module (section 3) and some details about the AT command parser (section 4), which is a very important component of the application. Next, it provides information on fundamental topics specifically related to SARA-R5, such as local connectivity (section 5), MNO profiles (section 6), network registration (section 7), power saving mode and eDRX (section 8). Another important functionality an application should include is monitoring the module status and reacting to possible issues in the correct way: details about this can be found in section 9. Section 10 describes how to use the +UTEST AT command for OEM production testing, while section 11 reports some indications about module factory restoring.

Other application notes are available to delve into specific topics, they are referenced in section 12.

Finally, a list of software changes with respect to SARA-R4 series modules is provided in section 13 and can be useful when migrating an application from R4 to R5 modules.

Table 1 shows a summary of the documentation available for SARA-R5 series modules.

	Document name	Notes
<b>Application integration</b>	Application development guide app note	This document. <b>Start here!</b>
	FW update app note [4]	FW update procedures (uFOTA, FOAT, FOTA, +UFWINSTALL, EasyFlash).
	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 app note [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.
	Mux implementation app note [8]	Usage of multiplexer with cellular modules.
	EVK-R5 user guide [10]	Starting guide for the SARA-R5 evaluation kit.
<b>Reference documentation</b>	Data sheet [1]	Use these documents as hardware integration and AT commands API reference.
	System integration manual [3]	
	AT commands manual [2]	
<b>Product release documents</b>	Sample Delivery Note / Information Note	Delivered with every FW release.

Table 1: SARA-R5 documentation overview

See the SARA-R5 series AT commands manual [2] for detailed AT command descriptions.

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



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



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

## 2 LPWAN technology overview

SARA-R5 series modules support LTE Cat M1 LPWAN technology, such as used in application areas:

- 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 allows the connection to IoT and M2M devices with medium data rate requirements. It enables longer battery lifecycles 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 part of the same 3GPP Release 13 standard that also defines Narrowband IoT (NB-IoT or LTE Cat NB1) - both are LPWA technologies in the licensed spectrum. With uplink speeds of 375 kbit/s, which can reach 1 Mbit/s on some networks thanks to protocol stack enhancements, and downlink speeds of 375 kbit/s in half duplex mode, LTE Cat M1 specifically supports IoT applications with low to medium data rate needs. At these speeds, LTE Cat M1 can deliver remote firmware updates over-the-air (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.

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.

As M stands for mobility, the LTE Cat M1 standard specifies Connected Mode Mobility, which SARA-R5 supports through inter-frequency and intra-frequency handover capability, resulting in higher reliability of transmissions, particularly important in non-static usage.

#### 2.1.1 Low power profile features

When integrating SARA-R5 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-R5 series system integration manual [3] and the SARA-R5 series AT commands manual [2]).

To benefit from the enhancement of the LPWA standard, PSM can be enabled. The PSM feature forces SARA-R5, when in inactive phases, 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 has to perform the periodic registration to the LTE network, which in PSM is done less frequently than in normal, non PSM operational mode (e.g. 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 (e.g. SMS) can rely on eDRX (extended DRX) to keep the power consumption at optimal level while retaining reachability.

SARA-R5 assures 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 following points, as depicted in [Figure 1](#):

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

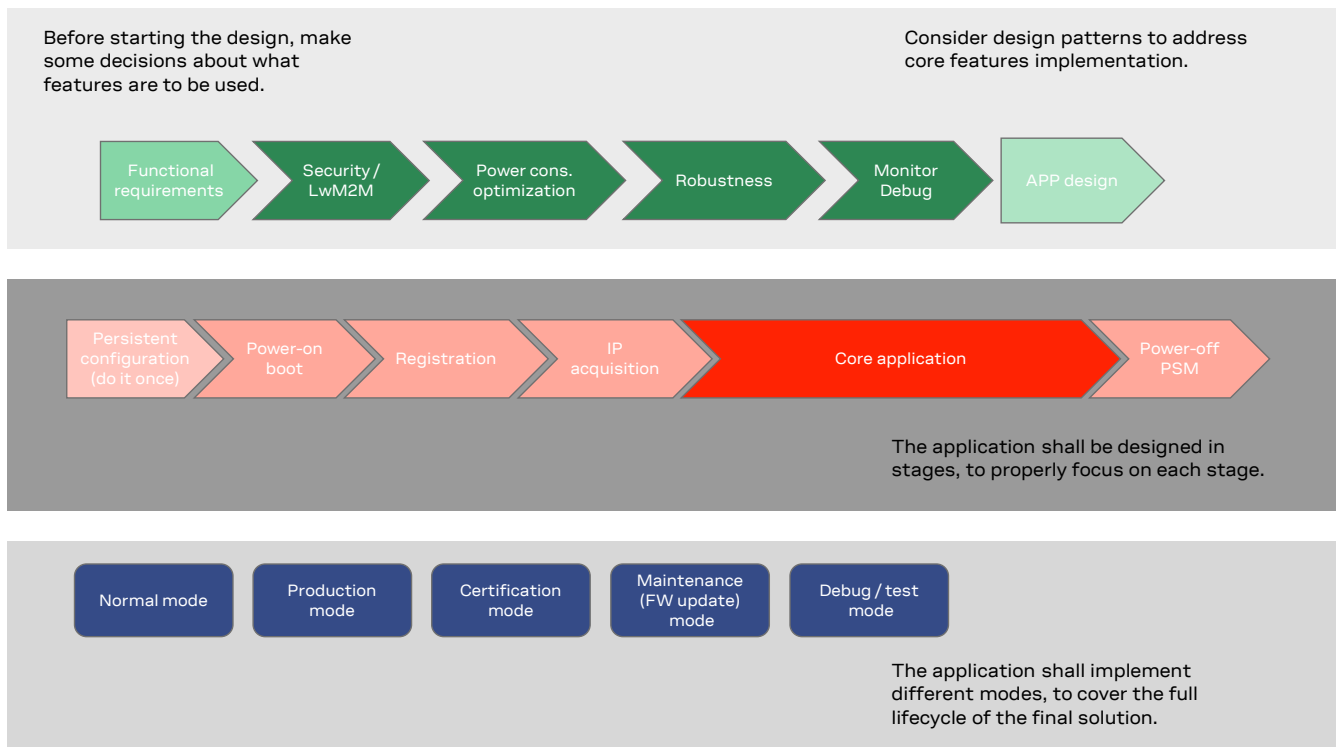


Figure 1: Application design

#### 3.1 Initial design decisions

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

These decisions concern:

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

An LwM2M client is necessary to allow MNOs to contact the device and retrieve diagnostic information; it enables also automatic periodic check of availability of FOTA updates, on both MNO and u-blox servers. Based on the target power consumption profile, the customer application can periodically enable the client in order to control features, such as the periodic LwM2M registrations

with the server or can implement alternative or additional methods to implement FW updates when triggers by e.g. prolonged out of service conditions or by specific events.

Similar considerations hold for the security client.

Power saving features (+UPSV, PSM, eDRX) shall be configured based on the target power consumption profile, based on the suggestions in section 8.

The MNO profile (section 6) to be used depends on the type of application and SIM card (regional or global roaming). If the SIM card belongs to an MNO for which the module has gained the type approval, the MNO profile is available in the FW and shall be used.


Debug-ability can be provided via test endpoints, access to the USB interface, and in general a prolific application log containing all AT commands strings exchanged with the module and diagnostic information sent by the module with timing information. Monitoring the module status is a requirement to implement, via HW or SW, recovery procedures as described in section 9.

## 3.2 Application stages

### 3.2.1 Persistent configurations

Some module settings are persistent, that is, they are stored in the module Non-Volatile Memory (NVM). Among them, MNO profile (see section 6), APN for Internet connectivity, active LTE bands. In addition to NVM, some settings (e.g. +IPR and +UPSV) are saved to the module profiles by means of AT&W command.

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

 See the SARA-R5 FW update application note [4] for persistence of settings after a FW update. If settings are not retained, they shall be reapplied as per section 3.2.2.


### 3.2.2 Power on/boot/PSM exit

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

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

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

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

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

### 3.2.3 Network registration

For details about the network registration stage, see section 6.

### 3.2.4 IP acquisition

For some details and guidelines on this topic, see the SARA-R5 Internet applications development guide application note [5].



### 3.2.5 Core application

For some details and guidelines on this topic, see the SARA-R5 Internet applications development guide application note [5] and SARA-R5 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.

### 3.2.6 Power-off

The application might need to switch off the module; both normal and emergency shutdown are described in the SARA-R5 series system integration manual [3].

## 3.3 Application modes

Usually an application is 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 performing other important steps in the product lifecycle.

### 3.3.1 Debug / test mode

In general, an application should always output a significant log, including the AT commands it issues and their responses, and implement monitoring 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 needed to provide an AT interface passthrough to allow access to diagnostic AT commands.

If the cellular communication is tested against a network simulator, use a suitable test SIM card (usually provided by the network simulator manufacturer). If a test SIM card is not available, make sure to disable authentication and integrity checks on the tester side (by proper setting) and on the module (by using the `+UDCONF=81,0` AT command, see SARA-R5 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 usually the main application is inactive, and AT commands can be used to properly configure the module and use its end user testing features (see section 10).

### 3.3.3 Certification mode

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

### 3.3.4 Firmware update mode

A module’s firmware update should be implemented either over the air or tethered when necessary. Each update strategy has its requirements and correct implementation, which should be followed to guarantee the success of the operation. See the SARA-R5 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.
- As suggested in the SARA-R5 series AT commands manual [2], always wait for at least 20 ms from 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 (e.g. `AT+CMEE=1` or `AT+CMEE=2`).
- Asynchronous commands (e.g. `+UMQTTT`) return an immediate final result code and final result via URC.
- Some AT commands return Intermediate Result Code (IRC) during command execution.

### 4.1 Operational modes of the AT interface

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

In Command Mode, the module (called DCE – Data Communication Equipment) can receive AT commands. Once an AT command is detected on the AT interface, the DCE processes it and might return to Command Mode by issuing a successful or an error response. Special AT commands lead the AT interface into intermediate states where, for example, SMS payload is expected, or raw/binary data is being exchanged (e.g., 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.

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 `AT&D` command, see SARA-R5 series AT commands manual [2].

For more details about the AT command interface settings see the AT command settings section on SARA-R5 series AT commands manual [2].

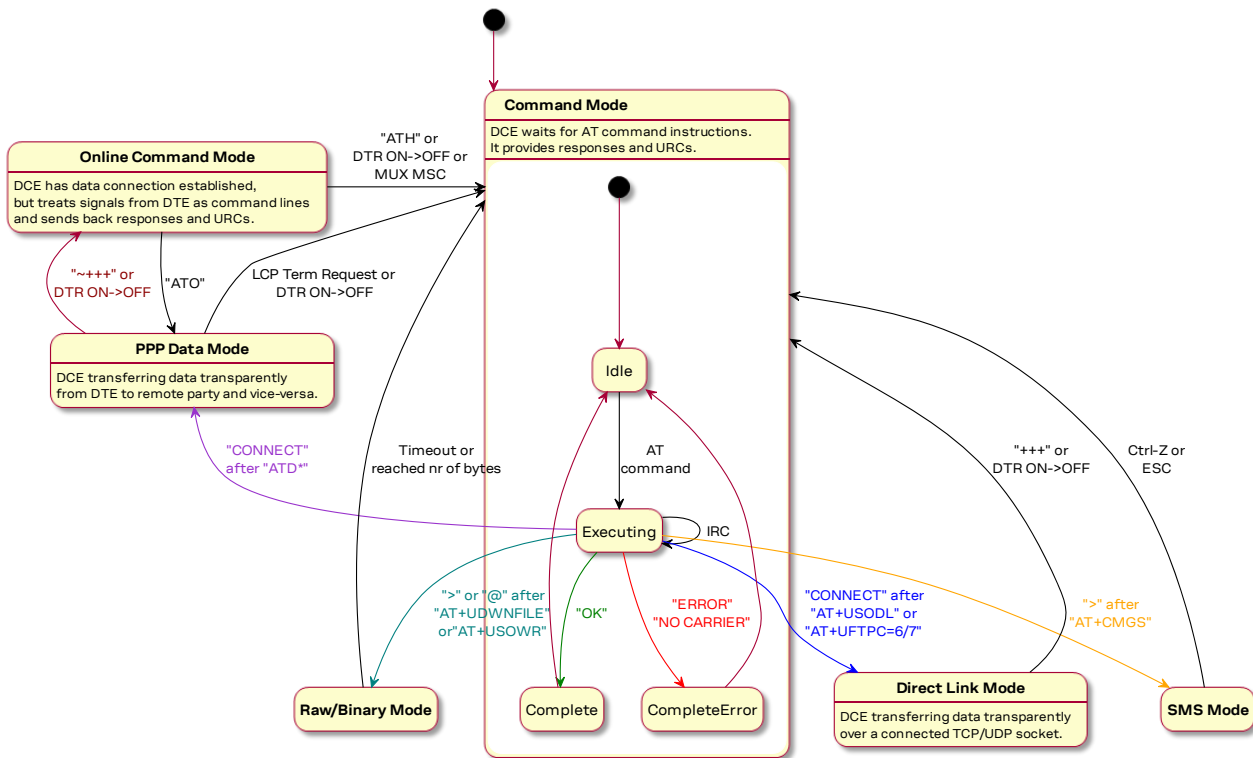


Figure 2: module operating modes and actions causing mode transitions

## 4.2 Unsolicited result code

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

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

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

Examples of some URCs are shown in [Table 2](#).

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: <stat>,<percent>	FOTA status update is in progress
+UUSOCL: <socket>	Socket has been closed

Table 2: URCs examples


## 5 Local connectivity

### 5.1 Serial interface configuration

It is possible to switch between 5 serial interface configuration variants, using the command `+USIO` AT command, as shown in [Table 3](#).

Command	Response	Description
<code>AT+USIO=0</code>	OK	(Default configuration) AT on UART (7-wire: RXD, TXD, CTS, RTS, DTR, RI, GND), TRACE on USB and SPI.
<code>AT+USIO=1</code>	OK	AT on UART (9-wire: RXD, TXD, CTS, RTS, DTR, RI, DSR, DCD, GND), TRACE on USB and SPI.
<code>AT+USIO=2</code>	OK	AT on UART and AUX UART (5-wire: RX/TX, HW flow ctrl, GND), TRACE on USB and SPI.
<code>AT+USIO=3</code>	OK	AT on UART (5-wire: RX/TX, HW flow ctrl, GND), TRACE on AUX UART (5-wire: RX/TX, HW flow ctrl, GND) and USB and SPI.
<code>AT+USIO=4</code>	OK	AT on UART (5-wire: RX/TX, HW flow ctrl, GND), GNSS tunneling on AUX UART (5 wire: RX/TX, HW flow ctrl, GND), TRACE on USB and SPI.

**Table 3: USIO variants description**

 Reboot is necessary to apply USIO configuration. For more details on `+USIO` AT command, see the SARA-R5 series AT commands manual [\[2\]](#).

### 5.2 AT interface

AT communication with SARA-R5 is possible via UART interface only.

By default, UART rate is set to “autobauding” (`+IPR: 0`). With “autobauding”, the module needs to wait for the first input from the DTE (Data Terminal Equipment) to detect the UART speed used by the host and apply it.


#### 5.2.1 Set a fixed baud rate

Use the `+IPR` AT command to set a different rate for UART as shown in [Table 4](#).

Command	Response	Description
<code>AT+IPR=115200</code>	OK	Set UART speed to fixed value 115'200. Cellular module response is sent at 115'200 bit/s.
After the «OK» final result code, wait for at least 100 ms before issuing a new AT command, to guarantee proper baud rate reconfiguration. Send commands at the speed previously set (115'200 bit/s in the example).		
<code>AT&amp;W</code>	OK	Store the configuration in the default profile in module's memory, in order to keep this setting at next module boots. If this step is skipped, the new UART speed will be kept only until next reboot.

**Table 4: setting a fixed baud rate example**

 To show a greeting text at module boot (`+CSGT` AT command), set a fixed baud rate beforehand by using `+IPR` AT command.

 If power saving is enabled with `AT+UPSV=1` or `AT+UPSV=3`, the usage of a fixed baud rate is suggested. If “autobauding” (`+IPR: 0`) and hardware flow control are used, the host application shall disable the hardware flow control before any reset / power-off and re-enable it at subsequent boot only after having first received a response from any AT command.

## 5.3 Multiplexer

SARA-R5 series modules support the multiplexer functionality as defined in the 3GPP TS 27.010 [12] on the UART physical link. This allows 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 3: AT commands / data connection.
- Channel 4: GNSS data tunneling (NMEA).

For further details about the usage of multiplexer with SARA-R5 modules, see the Mux implementation in cellular modules application note [8].

## 5.4 Point-to-point protocol (PPP)

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

 In case the double UART configuration is used, the full V24 modem lines are not supported. In this configuration, entering in OLCM (OnLine Command Mode) or disconnecting the PPP connection via DTR line de-assertion is not possible.

Further information about PPP dial-up establishment can be found in the SARA-R5 Internet applications development guide application note [5].

## 5.5 Generic guidelines

To properly configure local connectivity, the following steps shall be considered:

1. Set the required connectivity variant at first usage, 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.

## 6 MNO profiles

MNO profiles provide a powerful and flexible method to configure the SARA-R5 module to seamlessly work with the SIM of the selected network operator.


Using the MNO profiles the SARA-R5 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, 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 `+UMNPROF` AT command to select a profile for the network operator. See the SARA-R5 series AT commands manual [2] for details about the command.

### 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 on SARA-R5 modules is 90 (global profile).


 Reboot the module with `AT+CFUN=16` command 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

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 default.

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

For details about the settings applied by different MNO profiles, see appendix B.6 on the SARA-R5 series AT commands manual [2].

## 6.3 MNO profile setting examples

**Do not:** set the MNO profile while the module is registered ([Table 5](#))

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	+CME ERROR: operation not allowed	Cannot set MNO profile while module is registered.

**Table 5: wrong way of setting the MNO profile**

**Do:** de-register the module before setting MNO profile, then reboot it to apply the setting ([Table 6](#))

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=16	OK	Perform a module reset. After reboot, the MNO profile 100 settings are applied.

**Table 6: correct way of setting the MNO profile**

## 6.4 AT&T profile (+UMNOPROF: 2)

SARA-R5 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 (see the SARA-R5 series AT commands manual [2] for details). This setting is persistent.

Per AT&T requirement, LwM2M will predefine two +CGDCONT contexts with the following factory-programmed values:

- <cid>=0: IPV4V6,"m2m.com.attz"
  - This is a placeholder APN and shall not be used.
- <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.

## 6.5 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 (see +VZWAPNE AT command description in SARA-R5 series AT commands manual [2]).

SARA-R5 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. A brief description of the <cid>s in Verizon configuration is shown in [Table 7](#).

<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 7: <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.

## 6.6 Regulatory / Conformance profiles (+UMNOPROF: 0 / 201)

These MNO profiles can be used during production or lab tests. When using these profiles, LwM2M and security features are disabled.

## 6.7 SIM ICCID select profile (+UMNOPROF: 1)

It can be used by applications that will use different SIM cards. In this setting the Mobile Network Operator profile is selected according to the SIM Issuer Identifier Number (IIN) or IMSI, whose ranges can be configured by the application and stored to the file system.

By default, AT&T or Verizon profiles are detected based on IMSI, and global profile (+UMNOPROF: 90) is the fallback one. A reboot, triggered by the application or autonomously by the module, is necessary to have the detected MNO configuration applied. See the SARA-R5 series AT commands manual [2] for details on the AT command and URC syntax and reboot configurability.

 When setting MNO profile 1 via +UMNOPROF AT command, the second and third parameters (automatic reset and URC enabling) are mandatory!

Table 8 and Table 9 show examples of automatic MNO profile detection setting usage.

Command	Response	Description
AT+UMNOPROF=1,1,1	OK	Set the automatic MNO profile detection, the automatic reset and enable the related URC.
	+UMNOPROF: 1,2	URC reporting AT&T profile has been detected.
<module reboots>		Automatic reboot performed by the module.
AT+UMNOPROF?	+UMNOPROF: 1,2,1,1 OK	Read the detected profile.

**Table 8: setting automatic MNO profile detection with automatic reset example**

Command	Response	Description
AT+UMNOPROF=1,0,1	OK	Set the automatic MNO profile detection, the manual reset and enable the related URC.
	+UMNOPROF: 1,2	URC reporting AT&T profile has been detected.
AT+CFUN=16	OK	Host application triggers software module reset.
AT+UMNOPROF?	+UMNOPROF: 1,2,1,1 OK	Read the detected profile.

**Table 9: setting automatic MNO profile detection without automatic reset example**



# 7 Network registration

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

Once the module has found a suitable cell it can camp on, it will start the registration process. 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.

PIN lock shall be disabled in case the device is expected to work with PSM enabled.

## 7.1 Band configuration

SARA-R5 series modules 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, the bit at (band-1) position enables (if 1) or disables (if 0) the scan of the band. Some examples are depicted 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	SUM	BITMASK
Base 2	2 <sup>27</sup>	2 <sup>26</sup>	2 <sup>25</sup>	2 <sup>24</sup>	2 <sup>23</sup>	2 <sup>22</sup>	2 <sup>21</sup>	2 <sup>20</sup>	2 <sup>19</sup>	2 <sup>18</sup>	2 <sup>17</sup>	2 <sup>16</sup>	2 <sup>15</sup>	2 <sup>14</sup>	2 <sup>13</sup>	2 <sup>12</sup>	2 <sup>11</sup>	2 <sup>10</sup>	2 <sup>9</sup>	2 <sup>8</sup>	2 <sup>7</sup>	2 <sup>6</sup>	2 <sup>5</sup>	2 <sup>4</sup>	2 <sup>3</sup>	2 <sup>2</sup>	2 <sup>1</sup>	2 <sup>0</sup>		
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 <sup>19</sup>	524288
Enable B2, B4, B5, B12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	2 <sup>11</sup> +2 <sup>4</sup> +2 <sup>3</sup> +2 <sup>1</sup>	2074
Enable B4, B13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	2 <sup>12</sup> +2 <sup>3</sup>	4104

Use these values for AT+UBANDMASK

Figure 3: +UBANDMASK bitmask creation examples

Each MNO profile will define a set of bands to scan on.

### 7.1.1 Scan time

The scan time varies with the number of active bands. As a reference, Table 10 shows the scan time trend as the number of active bands increases, where SARA-R5 is registering to a live network sequentially with 2, 6, 10, and 14 bands enabled (+UBANDMASK AT command is used to select the number of bands to use for scan).

Number of bands scanned	PLMN scan + registration time on live network [s]
2	7.67
6	21.00
10	31.33
14	46.67

Table 10: Scan + registration time as the number of bands scanned increases

Values shown in Table 10 are indicative only and may vary depending on the network conditions. The purpose of the example is to show the linear trend between number of active bands and the PLMN scan and registration time.




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 borders 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.

## 7.2 First time registration setup

It is important to set the operator profile first because this operation will configure the default RAT and band mask for that corresponding profile.

The module is programmed with auto-cops, so no AT command is required to trigger the network registration. The `AT+COPS=0` command is strictly necessary only if the module starts up with auto-cops disabled, that is, `+COPS: 2` setting stored in the profiles per design (`AT&V`).

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

### 7.2.1 PAP/CHAP

In case PAP or CHAP authentication are to be configured, the `+UAUTHREQ` AT command shall be entered.

The command is not persistent, so in case the authentication is required on the initial default bearer, the setting shall be entered in de-registered state.

### 7.2.2 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 means of the `+CGDCONT` AT command, as shown in [Table 11](#).

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

Table 11: change of PDN settings example

### 7.2.3 Attach types

All profiles use Combined Attach (CS & PS); if successful, both data and SMS services are allowed.

The `+CEMODE` AT command can be used to change how the SARA-R5 series modules attach to the network if the default attach type is not accepted by the network.

## 7.3 Mobility scenarios

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

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

If mobility implies trespassing national borders or simply changing PLMN, it is likely that the new visitor PLMN will force the module to reattach. This can occur also on the RPLMN in case the network needs to e.g. refresh IP addresses.

### 7.3.1 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. 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 has to 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.
  - In case the eNodeB does not support CMM, 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.
  - To disable CMM for static applications with concern for downlink throughput, the `+UFGI` AT command can be used to disable FGI 13,14,16 and 25.
- 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. While in idle mode the UE will make measurements of neighboring cells and based on the cell reselection criteria read in the SIBs it may choose another serving cell to synchronize with.

## 8 PSM, eDRX and deep sleep mode

### 8.1 Power saving mode (PSM)

3GPP has standardized PSM as a way to minimize power consumptions for devices that require a sporadic access to the cellular network: instead of switching off the module at the end of the data transfer, the devices can negotiate long lasting periods (up to 413 days) during which registration can be postponed and mobile terminated traffic will be stored at NW side, thus letting the device skipping paging reception and entering a minimum functionality mode (PSM mode). Depending on the power saving settings (+UPSV), the SARA-R5 series modules can enter PSM deep sleep mode, where the module is running at negligible current (for definitions and power consumption characterization, see the SARA-R5 series system integration manual [3]).

The host application can preconfigure PSM on the module before registration or activate it runtime (see +CPSMS AT command), being the former solution to be preferred because the second one triggers a new registration to negotiate the PSM timers with the cellular network. Anyway, even if the PLMN does not allow PSM, the module will try to negotiate it at any registration procedure, periodic or due to mobility in other areas, as the PSM configuration is persistent in NVM. The +CEREG URC can report the assigned PSM timer values.

Three timers rule the entrance into PSM deep sleep mode, namely:

- T3324, the activity timer, which starts at the release of the RRC connection ordered by the NW, typically due to user inactivity. At T3324 expiry, the module can enter the PSM deep sleep mode. Paging will be sent by the eNodeB to the module only while T3324 has still to expire.
- T3412, which is the periodic TAU timer; by default, the cellular network configures it in ca 1 hour, but when the PSM is supported, the timer value can be negotiated up to 70 hours. During this period, the device is in deep sleep mode and paging messages will be queued at NW side. For this reason, some applications like LWM2M and security clients, that might be waiting for a response from the server, temporarily postpone the entrance of the module in the PSM deep sleep state.
- +UPSV timeout: this guard timer is set at the last character received on the UART interface and only if it is elapsed the module can enter deep sleep state.

If module enters PSM deep sleep state, it will locally deactivate MUX and PPP and will not be responsive to AT commands; it will either wake up autonomously at periodic TAU timer expiration, or through an early wake-up triggered by the host application via the PWR\_ON pin. The exit from PSM deep sleep state is similar to a power-on, with the major difference that no LTE attach will be performed and the previously activated EPS bearers and IP addresses will be locally restored: the module will reselect a cell of the PLMN he was registered and triggers data transmission or TAU procedures in case of early wake-up or wake-up at T3412 timeout respectively. Enabling of PIN check is deprecated when using PSM, because it will prevent the module from restoring the cellular connectivity until PIN is re-entered by the host application.

At PSM deep sleep state entrance, any timer used in the module other than T3412 will be discarded (e.g. application timers). As an exception to this, the following throttling timers are saved and restored at PSM exit: T3402, sever network failure (SNF, Verizon specific), T3346, T3396, and T3245 (if is configured in USIM).

If the power saving mode is not active (i.e. if +UPSV: 0) the module will not enter PSM deep sleep state, but a standard PSM state, whose power consumption is similar to +CFUN: 0 condition and the module is responsive on the AT interface.

## 8.1.1 PSM indications and PSM toggling

The host application can monitor the entrance in PSM and PSM deep sleep state in several ways:

- GPIO “module status indication” (see +UGPIOC AT command)
- V\_INT monitoring
- RXD monitoring (if RXD is low for more than 1 character)
- +UUPSMR URC (it returns ‘1’ when the module is about to enter PSM).

As the device can enter PSM also during data sessions (e.g. UDP, TCP or secure sockets) if there is an idle period long enough for the RRC connection to be released and T3324 to expire, e.g. in case of temporarily server outage or packet loss e.g. in low coverage or mobility; the host application can prevent the module from entering PSM by issuing AT commands before the +UPSV timeout is elapsed. When possible, this solution must be preferred to the temporary disabling of PSM via +CPSMS AT command, as the latter will cause two registrations to negotiate the new timers with the network.

## 8.1.2 GSMA recommendations

The selection of T3324 timer value is a trade-off between power consumption and responsiveness: low values save more battery life by allowing the UE to go into PSM state quicker, high values of T3324 will allow a longer time for the application server (AS) to respond to UE/MO data (e.g. acknowledgements, network initiated data). Anyway, given that T3412 is recommended to be set to at least 4 hours, it is suggested to provide a push method to trigger mobile terminated data from the AS.

As a rule of thumb, it is recommended to use a maximum ratio of 10% between T3324 and T3412.

Typical minimum values for T3324 might consider the DRX cycle. For example: 2\*DRX cycle (i.e., 2.56 s) + 10 s (buffer time at NW side) = 16 s. A 0 s timer duration is also allowed, provided that the RRC inactivity timer adopted by the NW might cover the data reliability application needs.

Customers are advised to test out both parameters to come to a value that best fits their use case and requirements in terms of power consumptions, delay, and reliability.

## 8.1.3 Timer values


### 8.1.3.1 Encoding of timer T3412


The extended TAU timer configured via +CPSMS AT command is encoded as GPRS timer 3 IE (see TS 3GPP TS 24.008 [11]).

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 (Note 1)
1	1	1	value indicates that the timer is deactivated (Note 2)

Example: "01000111" = 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 value shall be interpreted as multiples of 1 hour.

 If this timer unit is received, the T3412 extended value shall be considered as not included in the message

The network might not grant an extended TAU timer and fallback to a standard encoding of T3412, which will be indicated by the <Assigned\_Periodic\_TAU\_Format\_Type> parameter of +UCPSMS AT command response. In such case 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 2 seconds
0 0 1 value is incremented in multiples of 1 minute
0 1 0 value is incremented in multiples of decihours
1 1 1 value indicates that the timer is deactivate
    
```

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

### 8.1.3.2 Encoding of timer T3412

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
1 1 1 value indicates that the timer is deactivated
    
```

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

Example: "0000100" = 4 x 2 s = 8 s

### 8.1.4 Deep sleep state in out of service

The deep sleep state can be entered even in prolonged out of service conditions, provided that the host application has selected this optimization via the <suspend\_mode> parameter of the +URATCONF AT command. In particular, after unsuccessful PLMN searches performed for <scan\_time> seconds, the deep sleep state is entered for <power\_save\_duration> seconds, whose duration can be automatically increased at every cycle if configured with <PSD\_step>.

### 8.1.5 Example of usage of PSM

#### Persistent settings

Command	Response	Description
AT+CFUN=0	OK	De-register the module.
AT+UPSV=1,1000	OK	Enable power saving with ca 4.6 s timeout. All +UPSV modes other than +UPSV: 0 are required to enable the entrance into PSM deep sleep state.
AT&W	OK	Save +UPSV setting to the default profile, loaded at switch on.
AT+CEDRXS=0	OK	Disable eDRX.
AT+UPSMR=1	OK	Enable the +UUPSR diagnostic URC.
AT+CSCON=1	OK	Enable +CSCON diagnostic URC.
AT+CPSMS=1,,,"10100010" ,"00000011"	OK	Enable PSM with 6 s for T3324 and 120 s for T3412 (such small values can be used only for testing purposes!)
AT+CFUN=16	OK	[optional] If +UMNOPROF setting has been modified, a SW reset shall be triggered.

## Volatile settings

Command	Response	Description
AT+CEREG=4	OK	Enable the +CEREG URC with extended syntax to report negotiated PSM timer values. If issued in full functionality, the current status shall be queried via the +CEREG read command.
AT+CFUN=1	OK	[optional] If +CFUN: 0, turn on the modem, auto-cops feature will trigger registration. We assume PIN check is disabled when using PSM.

## PSM in normal mode


Command	Response	Description
	+CSCON: 1	During LTE attach, the module is in RRC connected state.
	+CEREG: 1,"1","0","1",7,,,"00100010","10111110"	After successful LTE attach, location information is returned, together with the PSM timer values assigned by the NW (120 s for T3324, 1800 s for T3412 in the present case).
AT+CEREG?	+CEREG: 4,1,"1","0","1",7,,,"00100010","10111110" OK	Same information will be returned by querying the +CEREG AT command.
AT+UCPSMS?	+UCPSMS: 1,,,"00100010","10111110",1	The NW assigned PSM timer values are returned also by the proprietary command +UCPSMS, whose last parameter indicates if the extended T3412 duration has been granted (1) or not (0), regardless of the timer effective duration.
	+CSCON: 0	At expiry of inactivity time on the network side, the RRC connection is released by the eNodeB. Timer T3324 is set.
	+UUPSMR: 1	T3324 elapses and the device can enter PSM deep sleep
AT	OK	If the UART interface is stimulated just after the URC is issued, the entrance in PSM deep sleep state will be postponed by +UPSV timeout. No temporal threshold can be provided, because the delay of saving information to NVM done at entrance in PSM depends on many factors. It is therefore assumed that the host application will use the AT interface on purpose to prevent the module from entering PSM.
	+UUPSMR: 0	At T3412 expiry (usually with 2 s tolerance) the module will exit PSM.
	+CSCON: 1	At T3412 expiry, TAU is performed.
	+CSCON: 0	At expiry of inactivity time on the NW side, the RRC connection is released by the eNodeB. Timer T3324 is set.
	+UUPSMR: 1	T3324 elapses and the device can enter PSM deep sleep.
	+UUPSMR: 0	At early wakeup, the module will exit PSM.
ATD*99**1#	CONNECT	At exit from PSM, PPP mode shall be locally restored. IP address will be the same assigned during attach, and uplink data can be sent to the NW without the need to re-register.

## 8.2 eDRX

SARA-R5 series modules support the 3GPP Release 13 feature Extended Discontinuous Reception (eDRX). This feature allows to reduce power consumption thanks to extended no reception intervals (up to 2621.44 s in LTE Cat. M1 RAT) that separate shorter periods (called PTW – Paging Time windows, up to 20.48 s in LTE Cat. M1 RAT) in which the module can be paged by the eNodeB.

More often, eDRX is used in alternative to PSM for applications that need more responsiveness from the module but still need to keep power consumption limited and can afford delaying the mobile terminated traffic for the eDRX cycle duration. In case PSM is also active, paging reception in the paging windows operates while the T3324 timer is running and therefore it is advisable to negotiate a T3324 timer duration longer than the eDRX cycle, otherwise eDRX will never be effective and reception of mobile terminated data or signaling will be postponed to the exit from PSM (see [Figure 4](#)).

The application can set the eDRX with `+CEDRXS` AT command and read the network assigned eDRX value using the `+CEDRXRDP` AT command.

 Enabling of eDRX might cause the delayed elapsing of internal module timers, whose timeout will be rounded to the next useful eDRX cycle.

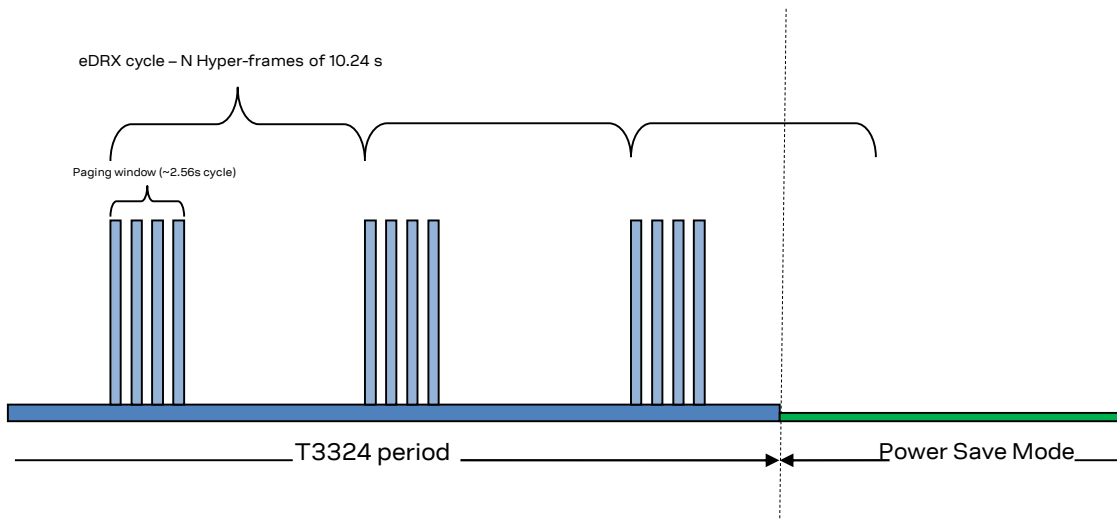


Figure 4: paging reception in PTW with both PSM and eDRX enabled

### 8.2.1 Functional diagram of eDRX and PSM

For sake of clarity, [Figure 5](#) illustrates the states transitions and the device activities during module operation with both PSM and eDRX active. Some configurable parameters are highlighted, among them the DRX cycle (2.56 s), the eDRX cycle (1024 s), T3324 and T3412 timers:

1. The device is in PSM deep sleep state; it has already registered at startup, negotiated PSM timers and is now inactive, not responsive to AT commands nor paging messages.
2. PSM is exited at early wake-up triggered by the host application or by T3412 timeout.
3. The device re-connects to network and sends and receives data or control packets.
4. The RRC connection is released by the network e.g. at the end of the TAU. The device enters the idle state and starts T3324 timer.
5. While T3324 timer is running, paging happens as per network 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 after 6 s (fixed timer, per design).

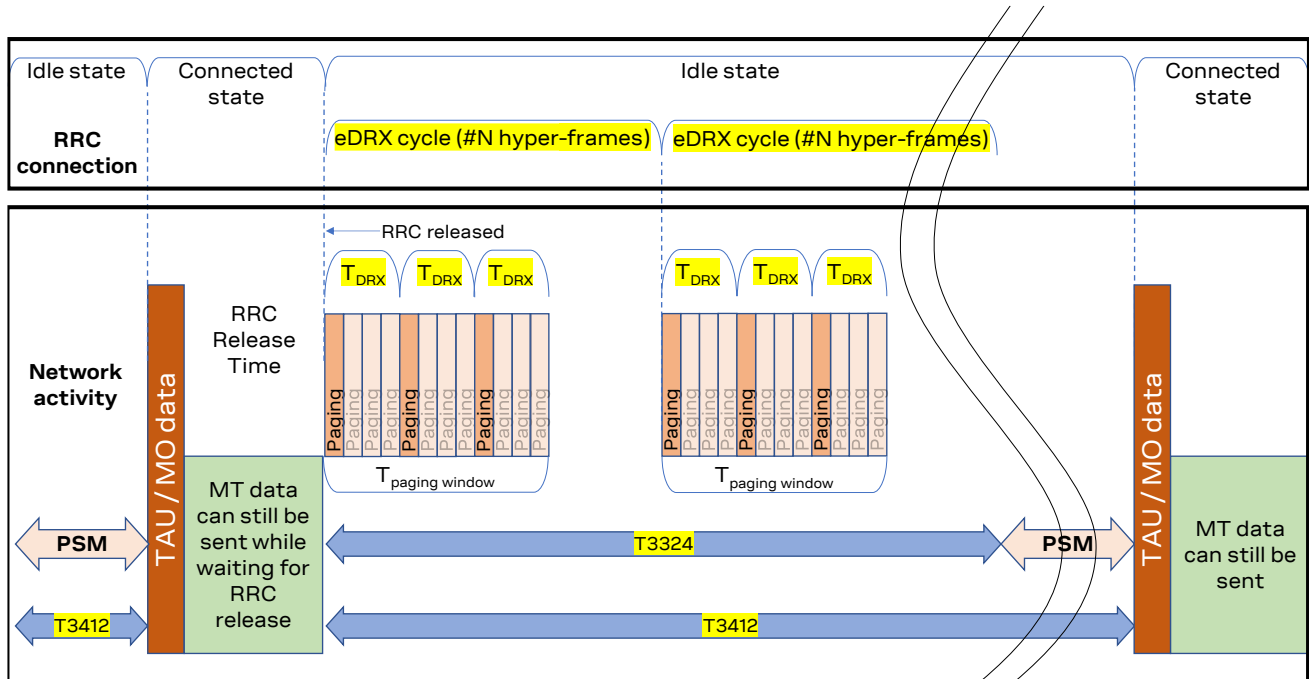


Figure 5: state transitions and module activity when both PSM and eDRX are enabled

### 8.3 PSM aware applications

Some embedded clients and features can alter the PSM timings; this holds in particular for LwM2M and security clients, which will temporarily postpone entrance into PSM deep sleep state until their sessions have been concluded.

IP based applications (e.g., MQTT, USOCK, UDNS, UFTP, HTTP) instead have no control on PSM, and might be negatively impacted by entrance in PSM state if the host application is waiting for an answer from the network, which is delayed beyond the T3324 timer duration. If the AT commands are asynchronous, like +UMQTT, the host application can enter AT commands until the final result code is received via URC. If the AT command is blocking, the UART interface can be polled on another virtual port or PSM can be temporary disabled via +CPSMS AT command.

Usage of UDP sockets instead of TCP ones can reduce the transactions duration and is more effective with respect to power consumption.

**⚠** Consider that in Coverage Extension mode the network may release the RRC connection later to accommodate the many retransmissions related to the CE mode currently selected by the UE. This can explain why PSM is sometimes entered with delay and can be confirmed by +CEINFO AT command.

## 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 to detect specific scenarios and implement proper handling and countermeasures in the host application.

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

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

Some AT commands provide a choice on how to handle the URCs when the AT interface is busy; for all other AT commands, URC is issued at the return into command mode, as explained in SARA-R5 series AT command manual [\[2\]](#), in the “URCs presentation deferring” section.

URCs and AT command responses are presented with their generic syntax because parameters names are quite explanatory; for precise meaning see the SARA-R5 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 (e.g. 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 NW.	Yes
AT+UCCELLINFO=2, <timer_value>	+UCCELLINFO: <mode>, <type>, <EARFCN>, <PhysCellID>, <RSRP>, <RSRQ>	Report serving and neighbor cell parameters with the specified periodicity.	No
AT+UMETRIC=<mode>[, <param1>]	+UMETRIC: [<mode>] [(URC's specific tags and values)]	Periodic or one-shot report of detailed diagnostic info. Periodicity can be set via AT+UMETRIC=5, <timer_value>. Long response tags (like LTE UE STAT) can be displayed only in case of connectivity issues for debug and logging purposes.	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=2	+CTZE: <tz>, <dst>[, <time>]	Enable reporting of changes in local time (+CTZU:1 is the factory default setting, so +CCLK will be automatically updated. Usually time and time zone info is provided by the NW 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 default ME or SIM, see AT+CPSM?) 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 persistent (can be saved in profiles via AT&W).	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 (e.g. IMSI swap, SIM profile installation after remote SIM provisioning). The setting is persistent.	No
AT+UBIP=2	+UUBIP: <ev_cmd>, <val>	URC are raised when Open Channel, Close Channel and Channel status events are issued by the SIM card towards the device to handle a SIM OTA session e.g. 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

Command	URC	Description	Can be polled
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.	
AT+ULWM2MSTAT=1	+ULWM2MSTAT: <event>,<param1>[,<param2>]	Enable URC to report the activity of the embedded LWM2M client. The setting is persistent.	
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 (e.g. repetitions schemes to be used) detected by the device or assigned by the NW.	Yes
AT+CEDRXS=1	+CEDRX: <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 NW in different areas or times. The setting is persistent.	Yes

## 9.1.2 Diagnostic information via polling

Command	Response (omitting OK)	Description	Suggested usage
ATI ATI9	SARA-R510M8S-00B-00 02.05,A00.01	Return the model and FW identification, useful for tracking purposes.	Module initialization
AT+CGSN	3412093481025938	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?		Return band mask selection.	Module initialization
AT+UMNOPROF?		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>,<Lr rc>,<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 NW. 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 (e.g. every 50 to 10 s)

Command	Response (omitting OK)	Description	Suggested usage
AT+CEER	+CEER: "EMM cause",15,"No suitable cells in tracking area"	It returns the last error cause (as received by the network) that led to the failure of a registration or PDN connectivity establishment.	When detecting registration or connectivity problems
AT+COPS?	+COPS: <mode>[,<format>,<oper>[,<Act>]]	It return the current registered PLMN in the configured format, RAT is fixed to 7 (LTE, Cat-M1).	Periodically (30 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>[,<NSLPT>[,<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 NW. As setting is persistent, if the NW 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 NW. 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)

## 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 SARA-R5 in the cellular mobile environment.


When a problem at a specific level is encountered, the countermeasure for that level should be tried and, if that does not resolve the issue, then proceed with the solutions for the lower levels. [Table 12](#) shows a full-stack watchdog for monitoring SARA-R5 series modules.


Level	Problem	Countermeasure	AT commands / actions	Notes
Socket/dial-up	Cannot send/receive data	Close and re-open socket	AT+USOCL=<socket_id> AT+USOCR=<protocol> AT+USOCO=...	
		Disconnect and re-connect dial-up	Send +++ / Move DTR ATD*99***<cid>#	
IP/PDP	Cannot get an IP address; cannot establish dial-up	Detach/re-attach	AT+CFUN=0 AT+CFUN=1	Consider possible restrictions to multiple <cid>s active for APN
		Deactivate/re-activate context (<cid> != 1)	AT+CGACT=0, <cid> AT+CGACT=1, <cid>	
Network registration	Cannot register	Detach/re-attach	AT+CFUN=0 AT+CFUN=1	AT+CFUN=0/1 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=16	
AT interface	No response from module	HW switch off	GPIO power on	See the SARA-R5 series system integration manual <a href="#">[3]</a> for details and alternatives

**Table 12: Full-stack watchdog for SARA-R5 series modules**

# 10 OEM production testing

The `+UTEST` AT command is used for non-signaling testing to verify proper assembly of the module and the involved parts in the OEM production line. It is intended for use by the manufacturer of the host device integrating the SARA-R5 module.

 `+UTEST` is not expected to be used for cellular RF performance measurements neither for certification purposes.

 The use of this command shall be restricted to controlled (shielded chamber/box) environments and for test purposes only. u-blox assumes no responsibility for inappropriate use of the command.

In particular, the `+UTEST` AT command allows to check all the RF parts and digital pins, that is, proper soldering of the **ANT** pad and related parts along the RF path, and GPIO functionality testing. The usage of this command should be restricted to controlled RF environments, such as shielded chamber/box, and shall be confined to validation and production tests.

The command requires entrance into test mode, so full functionality shall be restored after its usage.

It is suggested to test the module using the final MNO profile (if different from `+UMNOPROF: 1`, unless the final SIM card is used) and configuration (LwM2M, security, APN, etc.) and in all bands it will be operational (with `+UBANDMASK`).

If possible, it is suggested to use test SIM cards during production tests, possibly the same SIM card used during the device validation. If a test SIM card is not available, and in case the production tests are performed in signaling mode on a network simulator, make sure to disable authentication and integrity checks on the tester side (by proper setting) and on the module (by using the `AT+UDCONF=81,0` command, see SARA-R5 series AT commands manual [2]) and consider that LwM2M and security features might trigger uplink data transmission. Also consider that, at new SIM card detection, LwM2M will need about 20 s to populate its database and being ready to operate: this can be done in the production phase or once the device is deployed in the field.

## 10.1 Entering and exiting the RF non-signaling mode

Enable the UTEST mode to start using `+UTEST`; to do so issue `AT+UTEST=1` command.


 Deregister the module from the network before enabling UTEST mode. Use `AT+CFUN=0` to deregister from the network, otherwise the `"+CME ERROR: operation not allowed"` or `"+CME ERROR: 3"` (depending on the `+CMEE` AT command setting) will be reported.

Table 13 shows an example of entering non-signaling mode.

Command	Response	Description
<code>AT+UTEST?</code>	<code>+UTEST: 0</code> <code>OK</code>	Check the device is in signaling mode.
<code>AT+CFUN=0</code>	<code>OK</code>	Deactivate the protocol stack before entering the non-signaling mode.
<code>AT+UTEST=1</code>	<code>OK</code>	Enter the non-signaling mode.
<code>AT+UTEST?</code>	<code>+UTEST: 1</code> <code>OK</code>	Check the UTEST is in non-signaling mode.
<code>AT+UTEST=3,123130,23,,,5000</code>	<code>+UTEST: 123130,23,5,1,5000</code> <code>OK</code>	Example 1: TX test executed on B12 TX, Ch. 123130, 23 dBm, TX output for 5 s.
<code>AT+UTEST=2,105060,5000</code>	<code>+UTEST: 105060,5000,0,-21,-20,-19</code> <code>OK</code>	Example 2: RX test executed on B12 TX, Ch. 105060, RX measurement on for 5 s. The signal input to the receiver is reported at -20 dBm.

**Table 13: entering non-signaling mode with +UTEST**

After the desired tests have been executed, to return to the normal operating mode, perform one of these actions:

- Reset the module.
- Power-off the module.
- Send `AT+UTEST=0`. In this case, make sure to restore the full operational `+CFUN` mode via `AT+CFUN=1`.

## 10.2 Digital test

This test mode can be used during OEM production testing to check the correct behavior of the module’s digital pins and detect possible soldering or functional problems.

The `+UTEST` AT command can be used to configure a specific group of pins as:

- Digital input: once configured, it is possible to apply a voltage level to the pin.
- Digital output: the pin can be used to output a digital “high” or “low” voltage level.

Pins enabled for digital testing can be considered as generic digital input / output pins; it is possible to configure a pin as a digital output with “high” logic level and then verify the voltage level present at the pin. Conversely, it is possible to apply a “high” or “low” logic level on a pin set as a digital input, and then check if the module can correctly measure the voltage level applied.

[Table 14](#) reports number and type of pins available for digital testing via `+UTEST` AT command. For a detailed description of the input / output levels characteristics of the pins, see the SARA-R5 series data sheet [\[1\]](#).

Pin no	Name	Interface
6	DSR	UART
7	RI	
8	DCD	
9	DTR	
10	RTS	
11	CTS	
16	GPIO4	GPIO
18	RESET_N	
19	GPIO5	
23	GPIO2	
24	GPIO3	
25	GPIO1	
26	SDA	DDC
27	SCL	
33	GPIO6	GPIO
34	I2S_WA	Audio
35	I2S_TXD	
36	I2S_CLK	
37	I2S_RXD	
42	HW_TEST_MODE	
44	SDIO_D2	SDIO
45	SDIO_CLK	
46	SDIO_CMD	
47	SDIO_D0	
48	SDIO_D3	
49	SDIO_D1	

**Table 14: list of pins available for +UTEST digital testing**



### 10.3 Cellular RF functional test

As mentioned before, OEM manufacturers need only to verify proper assembly of the module in the OEM production line. This can be done by performing a simple RF functional test with basic instruments such as a spectrum analyzer (or an RF power meter), and optionally a signal generator, with the assistance of the +UTEST AT command over the AT command user interface.

In test mode, the module switches off the protocol stack for performing single tests which could not be performed during signaling. The +UTEST AT command provides a simple interface to set the module to RX or TX test modes ignoring the LTE signaling protocol. The command can set the module into:

- Transmitting mode in a specified channel and power level in all supported bands.
- Receiving mode in a specified channel to return the measured power level in all supported bands.

The minimum recommended RF verification in production consists in forcing the module to transmit in a supported frequency with the +UTEST AT command, and then checking that some power is emitted from the antenna system using any suitable power detector, power meter or equivalent equipment. For a detailed explanation of the hardware setup, see the SARA-R5 series system integration manual [3].

Table 15 and Table 16 report examples of RF tests using +UTEST, both in transmitting and in receiving modes.

Command	Response	Description
AT+CFUN=0	OK	Deactivate the protocol stack.
AT+UTEST=1	OK	Enter non-signaling mode.
AT+UTEST?	+UTEST: 1 OK	
AT+UTEST=3,119575,-30,,,1000	+UTEST: 119575,-30,5,1,1000 OK	The module transmits at channel 19575 (frequency 1747.50 MHz LTE band 3) for 1 s, after which the "OK" final result code is returned.  After the "OK" final result code, another +UTEST command can be sent.

Table 15: example of +UTEST RF Tx testing

Command	Response	Description
AT+CFUN=0	OK	Deactivate the protocol stack.
AT+UTEST=1	OK	Enter non-signaling mode.
AT+UTEST?	+UTEST: 1 OK	
AT+UTEST=2,101575,1500	+UTEST: 101575,1500,0,-70,-70,-70 OK	The module measures the receiver power level for 1.5 s at channel 1575 (frequency 1842.50 MHz LTE band 3).  After the time interval, the information text response contains: the channel number, the time interval and the minimum, average, maximum power levels.

Table 16: example of +UTEST RF Rx testing

Notes about RX test mode:

1. Use 100 kHz offset from center frequency of RF input signal. For example, to test EARFCN=2525 of LTE band 5, which corresponds to frequency = 881.50 MHz, set the signal generator frequency to 881.50 + 0.1 MHz = 881.6 MHz. Modulation settings are not required.
2. The minimum recommended +UTEST <par2> value (time of the measurement in ms) must be 10 ms. Using a lower value, the reported RX measurements may be not reliable.

## 10.4 Antenna dynamic tuner

The +UTEST AT command also allows the antenna dynamic tuner control by means of these parameters: <mode>=4 and <ant\_tuner\_enable>. This setting is stored in the NVM, and its configuration is effective also after exiting the test mode. After enabling this feature all the RF testing commands are executed with the antenna tuner control active.

When enabling the antenna dynamic tuner control by means of the AT+UTEST=4, 1 command, the I2S\_TXD and I2S\_WA pins are automatically configured as antenna dynamic tuning and their output changes according to the LTE band used by the module.

See the SARA-R5 series AT commands manual [2] for more details about +UTEST dynamic antenna tuner control.



Table 17 shows how to enable and disable the antenna dynamic tuner.

Command	Response	Description
<b>Enabling antenna tuner control</b>		
AT+UTEST=1	OK	Enter the test mode.
AT+UTEST=4, 1	+UTEST: 4, 1 OK	Enable antenna dynamic tuner control. All the following RX or TX activities are performed with antenna tuner control active.
<b>Disabling antenna tuner control</b>		
AT+UTEST=1	OK	Enter the test mode.
AT+UTEST=4, 0	+UTEST: 4, 0 OK	Disable the antenna dynamic tuner control.
AT+UTEST=0	OK	Enter the normal mode.

**Table 17: enable/disable +UTEST antenna dynamic tuner control**

# 11 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, that are updated with `AT&W` command, can be restored with `ATZ` command.
-  AT commands factory-programmed values stored in NVM and profiles are listed in appendix B.2 of SARA-R5 series AT commands manual [2].

The host application can restore the module factory configuration via the `+UFACTORY` AT command (see the SARA-R5 series AT commands manual [2]); this can be required to recover from an unexpected behavior and restart the module in a controlled configuration, or during the MNO certifications, where the device is tested in various simulated scenarios and the auxiliary information or previous user settings can affect the tests outcome.

Restoring the factory configuration of the module is a 2-step process:

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

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

Table 18 shows some examples.

Command	Response	Description
<b>Delete all files stored in FS</b>		
<code>AT+UFACTORY=2,0</code>	OK	Set <code>+UFACTORY</code> to delete all files in FS. No restore is performed so far.
<code>AT+UFACTORY?</code>	<code>+UFACTORY: 2,0</code> OK	Check the restore action currently set.
<code>AT+CFUN=16</code>	OK	Reboot the module. At next reboot, the restore action previously set is applied.
<b>Restore NVM</b>		
<code>AT+UFACTORY=0,2</code>	OK	Set <code>+UFACTORY</code> to restore the NVM. No restore is performed so far.
<code>AT+UFACTORY?</code>	<code>+UFACTORY: 0,2</code> OK	Check the restore action currently set.
<code>AT+CFUN=16</code>	OK	Reboot the module. At next reboot, customer settings and profiles are reverted to the factory programmed values.
<b>Cancel a restore operation (before reboot)</b>		
<code>AT+UFACTORY=2,0</code>	OK	Set a <code>+UFACTORY</code> action.
<code>AT+UFACTORY?</code>	<code>+UFACTORY: 2,0</code> OK	Check the restore action currently set. Currently, a FS restore is requested and will be applied at next reboot.
<code>AT+UFACTORY=0,0</code>	OK	Cancel any restore action.
<code>AT+UFACTORY?</code>	<code>+UFACTORY: 0,0</code> OK	No restore action will be applied at next reboot.

Table 18: `+UFACTORY` usage examples

## 12 Specialized application notes by topic

### 12.1 Multiplexer

See the Mux implementation in cellular modules application note [\[8\]](#).

### 12.2 IP based applications

See the Internet applications development guide application note [\[5\]](#).

### 12.3 Security suite

See the Security suite application note [\[6\]](#).

### 12.4 Secure communication

See the Internet applications development guide application note [\[5\]](#).

### 12.5 GNSS

See the SARA-R5 series GNSS implementation application note [\[7\]](#).

# 13 Software migration guide from SARA-R4 and general hints

Below is a list of changes between SARA-R4 and SARA-R5 series 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-R5 series AT commands manual [2].

- **+COPS behavior.** Issuing `+COPS` AT command while the module is in automatic search mode (`+COPS: 0`), the AT command may return `+CME ERROR: Temporary Failure`. This error result code can be neglected, and the command can be eventually retried. Ultimately, an `AT+CFUN=0/1` cycle can be issued to recover.
- **+CGDCONT behavior.** Differently from SARA-R4, on SARA-R5 when `AT+CGDCONT?` is issued after the attach is completed, the 3GPP suffix assigned by the network during the attach procedure is reported in the APN name field. For this reason, the APN name read with `+CGDCONT` read command may be different from the one set via the `+CGDCONT` set command.
- **+CGACT=0.** On SARA-R5, do not use `AT+CGACT=0`. Prefer `AT+CGACT=0,<cid>` or deregister the device with `AT+CFUN=0`.
- **Software reset via +CFUN.**
  - SARA-R5 supports `AT+CFUN=16` for software reset and `AT+CFUN=15` for software reset without reset of the SIM card.
  - SARA-R4 supports `AT+CFUN=15` for software reset.
- **Internal TCP stack.** In SARA-R5 it is needed to define and activate an internal PDP context (via `+UPSD` and `+UPSDA` AT commands) before using socket (`+USOXX`) and higher level IP based applications (`+UHTTP`, `+UMQTT`, etc.) commands. For more details, see the Internet applications development guide application note [5].
- **TCP socket graceful closure.** TCP socket (created via `+USOCR` AT command) graceful closure is obtained:
  - In SARA-R4, by using the `AT+USOCLCFG=1` command. The set command with value 0 disables the feature. This applies to all IP clients and applications.
  - In SARA-R5, by using the `+USOSO` AT command, specifying the option 128 (linger on close if data present) with values 1 (enabled) and linger time. This applies to `+USOXX` only applications.
- **MQTT client URCS.**
  - SARA-R4 "x2" product versions report 2 `+UUMQTT` URCS: one with the client result (`<MQTT_result>`) and another one with the server result (`<operation_result>`).
  - SARA-R5 and SARA-R4 "x3" product versions report the OK final result code right after the command, then only one `+UUMQTT` URC with the server result (`<MQTT_result>`).
- **SMS "ME" storage size.**
  - SARA-R4 "x2" product versions support up to 23 SMSs in "ME" storage.
  - SARA-R5 and SARA-R4 "x3" product versions support up to 100 SMSs in "ME" storage.
- **UART default data rate (+IPR).** The default and factory programmed value for the UART interface data rate is:
  - 115'200 bit/s on SARA-R4 series modules.
  - 0 ("autobauding") on SARA-R5 series modules. This impacts URC generation, that require an AT command to be printed at the proper UART speed.
- **+UCGED: PLMN format.** In the information text response to `+UCGED` read command, MCC and MNC parameters are printed in decimal notation on SARA-R4, while they are printed with hexadecimal notation on SARA-R5.
- **MNO profiles.** The available MNO profiles are different between SARA-R4 and SARA-R5 series. Always check the AT commands manual (`+UMNOPROF` AT command) of the specific product to get a list of available MNO profiles.

- **Disabling LwM2M.**
  - In SARA-R4 it can be disabled runtime but not permanently.
  - In SARA-R5 it can be permanently disabled.
- **PSM.** On SARA-R5, HPPLMN scan in roaming is not performed in PSM state, it will be postponed to PSM exit or PSM deep sleep exit. When USB is connected for debug purposes, PSM deep sleep state can still be entered. The `+URATCONF` AT command shall be used to configure entrance into deep sleep state in limited service or no service registration states.

# Appendix


## A Glossary

Abbreviation	Definition
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
PPP	Point-to-Point Protocol
PSM	Power Saving Mode
SW	Software
TAU	Tracking Area Update
UE	User Equipment
URC	Unsolicited Result Code

**Table 19: Explanation of the abbreviations and terms used**

## Related documentation

- [1] u-blox SARA-R5 series data sheet, [UBX-19016638](#)
- [2] u-blox SARA-R5 series AT commands manual, [UBX-19047455](#)
- [3] u-blox SARA-R5 series system integration manual, [UBX-19041356](#)
- [4] u-blox SARA-R5 FW update application note, [UBX-20033314](#)
- [5] u-blox SARA-R5 Internet applications development guide application note, [UBX-20032566](#)
- [6] u-blox IoT Security-as-a-Service application note, [UBX-20013561](#)
- [7] u-blox SARA-R5 series 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, [UBX-18068860](#)
- [10] u-blox EVK-R5 user guide, [UBX-19042592](#)
- [11] 3GPP TS 24.008 - Mobile radio interface layer 3 specification
- [12] 3GPP TS 27.010 V3.4.0 - Terminal Equipment to User Equipment (TE-UE) multiplexer protocol (Release 1999)

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

## Revision history

Revision	Date	Name	Comments
R01	28-Oct-2020	mmar	Initial release



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