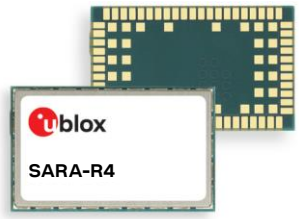
SARA-R4 series

Application development guide

Application note



Abstract

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

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Document information

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This document applies to the following products:

Product name	
SARA-R4	Except "00" and "01" previous versions

Contents

1 Introduction

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

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

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

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

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

2 LPWAN technology overview

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

Key applications using LPWAN include:

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

2.1 LTE Cat M1

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

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

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

2.2 NB-IoT

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

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

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

3 Application design

Applications using the SARA-R4 series modules must take into account the various features of the LPWAN technology. Proper configuration and operation of the module is key for a successful application.

Some areas of important consideration are:

- Power on / off sequence (Vcc must not be removed without issuing +CPWROFF AT command first)
- Mobile network operator (MNO) profile:
  - Automatic (SIM selected)
  - Specific MNO
- Radio Access Technology & band selection:
  - LTE Cat M1
  - NB-IoT
  - 2G
- Cellular registration:
  - Default EPS bearer
  - APNs
- 3GPP Release-13 power saving features:
  - PSM
  - eDRX
- Status / error handling:
  - Registration status; barred, roaming, unknown states
  - EPS bearer, activation, PDP context, APNs
  - Socket errors / closure
  - Power saving features (+UPSV & 3GPP PSM)
- Firmware Update Over the Air (uFOTA):
  - Application must handle the uFOTA upgrade process (see Firmware update application Note [4])

4 Power-on/off sequence

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

4.1 Power-on

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

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

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

☞ Before the SARA-R4 series module is fully ready to operate, the host application processor should not send any AT command over AT communication interfaces (USB, UART) of the module.

☞ The duration of the SARA-R4 series modules' switch-on routine can vary depending on the application / network settings and the concurrent module activities.

☞ The host application can use the `+CSGT` AT command to configure a known greeting text after the module boot to tell when the AT interface is operational.

☞ The host application can use the `+UGPIOC` AT command to configure a GPIO pin to denote when the AT interface is operational.

4.2 Power-off

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

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

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

⚠ Currently the only way to know when to remove **VCC** is to monitor **V_INT** pin and wait until it is at 0 V.

⚠ An abrupt removal of the **VCC** supply during SARA-R4 series modules normal operations may lead to an unrecoverable faulty state and must be avoided.

⚠ Forcing a low level on the **RESET_N** pin during SARA-R4 series modules normal operations may lead to an unrecoverable faulty state and must be avoided.

5 AT command response parser

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

In this document the following naming conventions are used:

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

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

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

5.1 Unsolicited result code

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

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

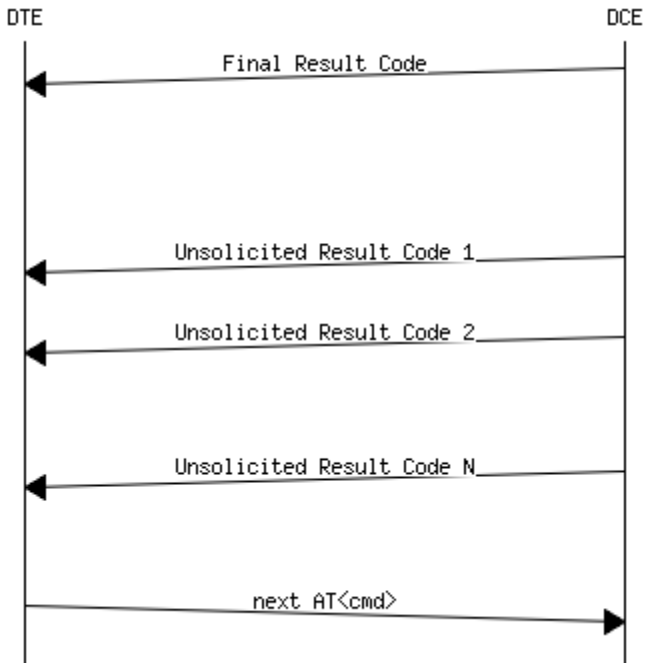


Figure 1: DTE-DCE URC flow chart

5.2 Best practices

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

6 Port selection

6.1 AT interface

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

The module requires a number of seconds to boot, between 4 or 5 s, before the AT interface is available to the application processor.

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

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

6.1.1 Interface power saving

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

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

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

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

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

6.2 Multiplexer implementation (UART)

SARA-R4 series modules support the multiplexer as defined in the 3GPP TS 27.010 [10]. This allows the control channel to operate on one channel and AT commands to operate on another channel.

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

6.2.1 DLCI mapping (channel support)

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

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

6.2.2 Limitations

The multiplexer implementation has the following limitations:

- **9600 b/s baud rate is not supported.**
- When an AT command (except ATD) is sent on the channel 1, the application must wait for a response prior to sending another AT command on any other channel and vice versa
- For commands such as +URDFILE and +USODL, that do not return "OK" right away, the application must wait for the command to finish execution and return the "OK" final result code prior to sending another AT command on any other channel and vice versa.
- When ATD is sent on the channel 1 and displays "CONNECT" intermediate result code, the application may proceed to send another AT command on any other channel and vice versa.
- When a dial-up call is active on the channel 1, the application cannot use any AT commands that require data services on any other channel. This includes FTP, HTTP, and sockets.
- The +CMUX command cannot be used again once the multiplexer has been enabled.
- The UART baud rate cannot be changed after the multiplexer enabling, so the +IPR command should be used to set the desired baud rate prior to using the +CMUX command.
- The software flow control (XOn/XOff) is not supported and should be disabled.
- Multiplexer power control and wake-up mechanism (as described in the 3GPP 27.010 TS [10]) are not supported.
- The multiplexer is supported only on the UART interface. Only one interface can be used at a time.
- If direct link mode +USODL is used on one channel, then AT commands functionality over any other channels will not be available.
- The RI indication for an incoming SMS through the MUX MSC message is not supported.
- When the MUX is used, the URC to indicate when an incoming SMS is received is not supported.

6.3 RING indication

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

☞ When the module is in PSM, the RING indication will not be emitted.

☞ The GPIO can also be configured to note when the AT interface is ready. This can be used to detect when the module has been woken up from PSM. See the +UGPIOC AT command description for further information.

7 MNO profiles

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

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

With the MNO profiles, customer application is not required to configure the module using complex and/or network-dependent parameters, but benefits from a “out of the box” solution that provides seamless connectivity while abstracting the complexity of managing individual network configurations. MNO profiles are decoupled from the module firmware and therefore can be dynamically updated (for example in case of network parameters change) - even after deployment - without the need of updating the modem firmware.

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

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

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

☞ To view the list of available MNO profiles, use the `+UMNOPROF` test command.

☞ Use `AT+UMNOPROF=,1` to enable the version text of the profile when they are listed using the above command. For more details, see the firmware update application note [4].

⚠ For use on other networks that are not listed, if it is available on the product, use the MNO profile 100 (standard European) and configure RATs and bands accordingly.

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

7.1.1 Using MNO profiles

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

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

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

☞ The host application must specify a MNO profile.

☞ Reboot the module with `AT+CFUN=15` to make the MNO profile active.

7.1.2 MNO profile 0 (undefined)

It is strongly recommended to configure the module to the applicable MNO profile, RAT, and LTE bands intended for the application device and within regulatory compliance. The module is not intended be used in the MNO profile 0.

7.1.3 MNO profile 1 (SIM ICCID select)

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

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

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

See Appendix C for IIN values stored in lookup database.

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

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

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

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

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

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

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

7.1.4 MNO profile 100 (Standard Europe)

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

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

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

7.1.5 MNO profile 101 (Standard Europe No-ePCO)

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

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

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

7.1.6 MNO profile 102 (Standard JP)

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

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

7.1.7 MNO profile 3 (Verizon)

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

7.1.8 Modifiable parameters

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

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

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

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

7.1.9 Resetting MNO profile parameters

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

8 Registration with LPWAN network

At the power-on the module reads the information in the currently selected MNO profile. It will use this information to configure which bands to scan, the radio access technology to use and other attach parameters.

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

Use +CNUM and +CGDCONT AT read commands to view the assigned MDN number and APN assigned after the module has registered on to the network, but not all network operators assign a MDN.

The +COPS AT read command can be used to view the network information, and +CESQ to check the signal conditions.

The module requires to be configured to the desired MNO profile for it to function properly on the network it is intended to be used on. Set the MNO profile on the very first use, or after flashing new firmware.

Applications shall select a proper MNO profile and not leave the factory-programmed undefined profile.

8.1.1 Radio Access Technology (RAT)

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

Each MNO profile has a defined RAT search priority.

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

8.1.2 Band configuration

SARA-R4 series modules can scan over a number of bands to find a network to attach to. The host application can limit the scanning to specific bands to shorten the time to find a network.

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

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

Use these values for +UBANDMASK

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

LTE Cat M1 and NB1 both have individual band masks, which need to be configured separately. AT+UBANDMASK=0,<band mask> for LTE Cat M1, AT+UBANDMASK=1,<band mask> for NB1.

8.1.3 Scan time

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

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

8.1.4 First time registration setup

It is important to set the operator profile first because this operation will configure the default RAT and band mask for that corresponding profile. If applied after `+URAT` or `+UBANDMASK`, it will override any past configuration the host application has made.

☞ The host application should always set the MNO profile.

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

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

Possible reason for setting `+URAT` may include:

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

Possible reason for setting `+UBANDMASK` may include:

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

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

Step #1: Set the profile to standard Europe

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

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

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

Step #3: Set +UBANDMASK

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

The above two steps can be combined as such:

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

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

8.2 Registration as PS connection

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

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

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

8.2.1 PS connections at RAT change

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

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

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

8.3 Detecting the access technology

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

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

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

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

Basic operation would be:

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

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

8.4 Mobility

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

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

If the application has configured multiple RATs in the +URAT setting, in case the module cannot select a cell on the same RAT, it will automatically go through a re-selection process selecting a cell of another RAT. In this case, PDP contexts will be locally deactivated and socket connections disconnected accordingly.

8.4.1 Mobility Management procedures

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

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

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

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

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

8.4.2 Cell to cell (same RAT), connected mode

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

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

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

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

8.4.3 Cell to no coverage, connected mode

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

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

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

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

8.4.4 Cell to cell (same RAT), idle mode

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

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

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

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

8.4.5 Cell to no coverage, idle mode

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

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

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

8.4.6 Inter-RAT handover and change or RAT

Inter-RAT handover is currently not supported.

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

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

8.5 Registration examples

8.5.1 LTE registration (Cat M1, NB-IoT)

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

Command	Response	Description
`AT+UMNOPROF=100`	`OK`	Set the standard Europe profile
`AT+CFUN=15`	`OK`	Reboot to take effect
`AT+URAT=8`	`OK`	Set +URAT to NB-IoT only
`AT+CFUN=15`	`OK`	Reboot the module to take effect
`AT+UBANDMASK=1, 524288`	`OK`	Set band to 20 only for NB-IoT
`AT+CGDCONT=1,"IP","jtm2m"`	`OK`	Set APN to “jtm2m”
`AT+CFUN=15`	`OK`	Reboot the module to take effect

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

Command	Response	Description
`AT+CEREG?`	`+CEREG: 0,2` `OK`	Module is still scanning
`AT+CEREG?`	`+CEREG: 0,5` `OK`	Registered to network (roaming)
`AT+CGATT?`	`+CGATT: 0` `OK`	Module is not attached to network yet
`AT+CGATT?`	`+CGATT: 1` `OK`	Module is attached to network
`AT+CGACT?`	`+CGACT: 1,0` `OK`	Module does not yet have an active PDP context
`AT+CGACT?`	`+CGACT: 1,1` `OK`	Module now has an active PDP context
`AT+CGDCONT?`	`+CGDCONT: 1,"IP","j2m2m","91.80.104.82",0,0` `OK`	Module has an IP address
`AT+USOCR=17`	`+USOCR: 0` `OK`	Create a UDP socket. Socket ID 0 is returned

Command	Response	Description
AT+USOST=0,"195.34.89.241",7,2,"AB"	+USOST: 0,2 OK	Send 2 bytes to u-blox echo server
<wait for +UUSORF URC>	+UUSORF: 0, 2	Socket ID 0 has 2 bytes to read
AT+USORF=0,2	+USORF: 0,"195.34.89.241",7,2,"AB"	Read back 2 bytes from socket ID 0
AT+USOCL=0	OK	Close socket ID 0

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

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

Command	Response	Description
AT+UMNOPROF=100	OK	Set the profile. In this example MNO profile100 is selected, since it provides access to 2G RAT[1].
AT+CFUN=15	OK	Reset the module to complete activate the MNO profile selection.
AT+UMNOPROF?	+UMNOPROF: 100	Check the MNO profile comes up after boot. In this example it is verified correct with 100.
AT+URAT=9	OK	Set +URAT to 2G only. Only selected profiles allow URAT to be reconfigured.[1]
AT+CFUN=15	OK	Reboot the module to take effect.
AT+CGDCONT=1,"IP","jtm2m"	OK	Set APN to “jtm2m”.
AT+CFUN=15	OK	Reboot the module to take effect.

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

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

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

8.5.3 SIM Issuer Identification Number detection

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

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

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

- If the IIN is a valid SIM listed in the internal database, it will then automatically set the MNO profile followed by a module reset to allow the profile to take effect.
- If the SIM is not valid, the module will set itself to minimum functionality (+CFUN: 0) to disable the radio. In this case, the host cannot change this to +CFUN: 1 (full functionality).

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

See Table 3 for IIN values stored in lookup database.

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

9 Data delivery

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

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

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

9.1 Data planes

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

9.2 Attach types

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

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

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

10 PDP context / Access Point Name (APN)

10.1 Default APNs

When using the +UMNOPROF AT command, a pre-defined APN may be set for the specified network. For more details, see the section 7.1.1.

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

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

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

10.1.1 Verizon attach APN

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

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

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

10.2 Multiple & private APNs

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

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

10.3 Authentication

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

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

☞ The password comes before the username.

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

11 DUN/PPP

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

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

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

☞ For SARA-R410M-02B-00 and SARA-R410M-52B-00, to avoid conflict with the internal uFOTA client service, the PPP operation should be entered within 30 s of the module boot. If the DUN/PPP (ATD#99) establishment fails, the application should retry.

☞ For SARA-R410M-02B-01, SARA-R410M-52B-01, SARA-R412M-02B-00, SARA-R412M-02B-01, and SARA-R4 "63" / "73" / "83" product versions the uFOTA client starts earlier from boot and therefore in contrast to previous firmware it should be attempted 30 s after the module boot.

☞ If the LWM2M LifeTimer should expire during the middle of the module's run time after boot a DUN/PPP establishment will fail, and the application should retry.

☞ In regards to device security and data security for SARA-R4 "63" / "73" / "83" product versions, a PPP/DUN call cannot be established when:

- The device attempts to connect to the u-blox security server to perform a bootstrap
- When a security heartbeat time expires and it attempts to connect to u-blox security service server
- When the encryption / decryption feature attempts to connect to owner's platform.

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

For more details on device security and data security, see u-blox security suite application note [6].

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

☞ After the module has attached to the network the host can control the PDP context APN, authentication and MTU sizes directly through PPP.

☞ For Windows and non-Windows hosts, the AT&S0 command is needed.

☞ For Windows dial-up the command ATX0 should be configured as the initialization string under advanced properties of the modem.

☞ If the network throughput is less than the data sent from the host to the module (is limited by uplink network resource/bandwidth), then a packet data loss may occur, even with hardware flow control enabled. To avoid this issue do either or both:

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

☞ When using MUX and PPP combined, toggling the DTR line does not terminate the PPP session and return the device to the command mode. In this configuration, it is recommended that the host terminates the PPP session, which can be done by sending LCP_TERM REQ. Another method to terminate the PPP session is to send a MSC MUX frame for logical DTR de-assert.

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

11.1 PPP over multiple PDP contexts

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

☞ A different and unique APN is required per context.

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

Example of a second context for PPP dial up connection:

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

For more details on multiple PDP contexts, see the SARA-R4 series AT command manual [2].

12 Monitoring module status

12.1 Registration status

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

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

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

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

The +CEREG URC can be enabled to provide the network registration status. Depending on the <mode> parameter it is possible to configure the parameters of interest. For more details, see SARA-R4 series AT commands manual [1].

☞ Setting the +CEREG <mode> parameter to 3, 4 or 5 it is possible to see the registration EMM cause value. These values are described in the 3GPP TS 24.008 [8]. Typical causes:

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

12.2 Viewing IP address

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

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

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

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

12.3 Viewing DNS address

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

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

12.4 AT example

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

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

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

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

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

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

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

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

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

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

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

13 TCP/UDP sockets

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

☞ If the module changes RAT any sockets opened at the time will be closed.

☞ Any open sockets will be kept open if the module loses the previous cell and can camp on another cell without timing out scanning for the new cell.

13.1 Packet switched data configuration – IPv4/IPv6

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

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

Command	Response	Description
`AT+UPSD=0,0,1`	`OK`	Set profile 0, protocol IP type to IPv6

13.2 Domain name addresses

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

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

13.2.1 DNS caching

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

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

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

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

13.3 Socket buffers

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

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

13.4 Creating a socket

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

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

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

13.5 Closing a socket

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

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

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

☞ Issue the +USOCLCFG AT command to enable or disable the closing of the TCP socket on the remote system when the module is in idle mode. If enabled the module will re-establish the RRC connection and send a message to the server closing the socket. When this is disabled the module will leave the server's socket open when it goes into idle mode.

☞ The +UUSOCL URC will not be issued if the remote host closes the socket until all the received data has been read using the +USORD AT command.

Per TCP RFC 793 [12], the client can specify a "TIME_WAIT" value, commonly named as linger timer, for the above socket closing process. Lowering this value could reduce the socket closure time, but by doing so it would trade off time to ensure the last ACK is sent from the client to the server, where in context the client is referred to as the initiator of the TCP session and the receiver is the server.

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

13.6 UDP

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

13.6.1 Sending data

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

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

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

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

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

13.6.2 Receiving data

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

13.6.2.1 Data arrived indicator

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

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

13.6.2.2 Reading data from socket

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

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

13.6.3 Testing

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

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

Here is an example:

Command	Response	Description
AT+USOCR=17	+USOCR: 1 OK	Create a socket. The socket ID is 1.
AT+USOST=1,"195.34.89.241",7,5,"48656c6c6F"	+USOST: 1,5 OK	Send “Hello” to u-blox echo server. Sent 5 bytes on socket ID 1.
	+UUSORF:1,5	Received 5 bytes on socket ID 1.
AT+USORF=1,5	+USORF: 1,195.34.89.241,7,5,"48656c6c6F" OK	Read 5 bytes on socket ID 1. Received data information provided… “Hello”.

13.7 TCP

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

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

13.7.1 Connecting to server

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

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

13.7.2 Writing socket data

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

13.7.3 Receiving data

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

14 MQTT

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

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

14.1 Quick start based on minimal MQTT configuration

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

14.1.1 Restore MQTT to factory–programmed setting

The following command restores factory–programmed parameters to MQTT:

```
AT+UMQTTNV=0
```

☞ This will overwrite all of the MQTT profile parameters currently in the NVM.

☞ Do not execute this command if there is current active MQTT login connection. Otherwise the MQTT profile parameters for that connection will be lost.

14.1.2 MQTT client ID specification

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

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

14.1.3 MQTT remote server specification

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

14.1.3.1 Server IP address

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

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

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

14.1.3.2 Server name

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

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

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

14.1.4 MQTT connection

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

```
AT+UMQTTC=1
```

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

```
+UUMQTTC: 1,0        for SARA-R4 “02” / “52” product versions
+UUMQTTC: 1,1        for SARA-R4 “63” / “73” / “83” product versions
```

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

14.1.5 Additional configuration

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

14.2 Quick start based on saved NV configuration

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

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

14.2.1 Restore from saved NVM - MQTT profile

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

```
AT+UMQTTNV=1
```

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

14.2.2 MQTT connection

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

```
AT+UMQTTC=1
```

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

```
+UUMQTTC: 1,0        for SARA-R4 “02” / “52” product versions
+UUMQTTC: 1,1        for SARA-R4 “63” / “73” / “83” product versions
```

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

14.3 Connection commands

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

14.3.1 Subscribe to MQTT topic filter

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

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

After the MQTT client receives a:

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

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

14.3.1.1 Example

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

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

14.3.2 Publish MQTT message to topic name

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

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

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

14.3.2.1 Example

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

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

14.3.3 Read MQTT messages received

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

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

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

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

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

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

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

```
AT+UMQTTC=6
+UMQTTC: 6,1
OK
+UMQTTCM: 6,<Num_unread_msgs>
<topic_name>
<message>
<topic_name>
<message>
…
OK
```

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

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

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

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

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

14.3.4 Logout

The following command terminates the MQTT connection:

```
AT+UMQTTC=0
```

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

14.4 Profile parameters

14.4.1 Login credentials

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

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

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

14.4.2 Client ID

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

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

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

14.4.3 “Will Message” configuration

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

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

This command defines the <Will_Message> parameter:

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

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

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

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

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

15 HTTP

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

15.1 HTTP with server name only

Example of HTTP with basic server name only:

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

15.2 HTTP with basic authentication

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

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

15.3 HTTPS with SSL/TLS security certificate

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

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

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

16 Secure data

16.1 Certificate format

SARA-R4 series modules do not support the PEM format. Only DER and CER formats are supported.

For a useful reference on how to convert certificates from PEM format, see the support SSL website.

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

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

16.2 DTLS client

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

☞ For more details on DTLS, see RFC 6347 [11].

16.2.1 AT commands examples for DTLS client

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

17 Non-IP messaging

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

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

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

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

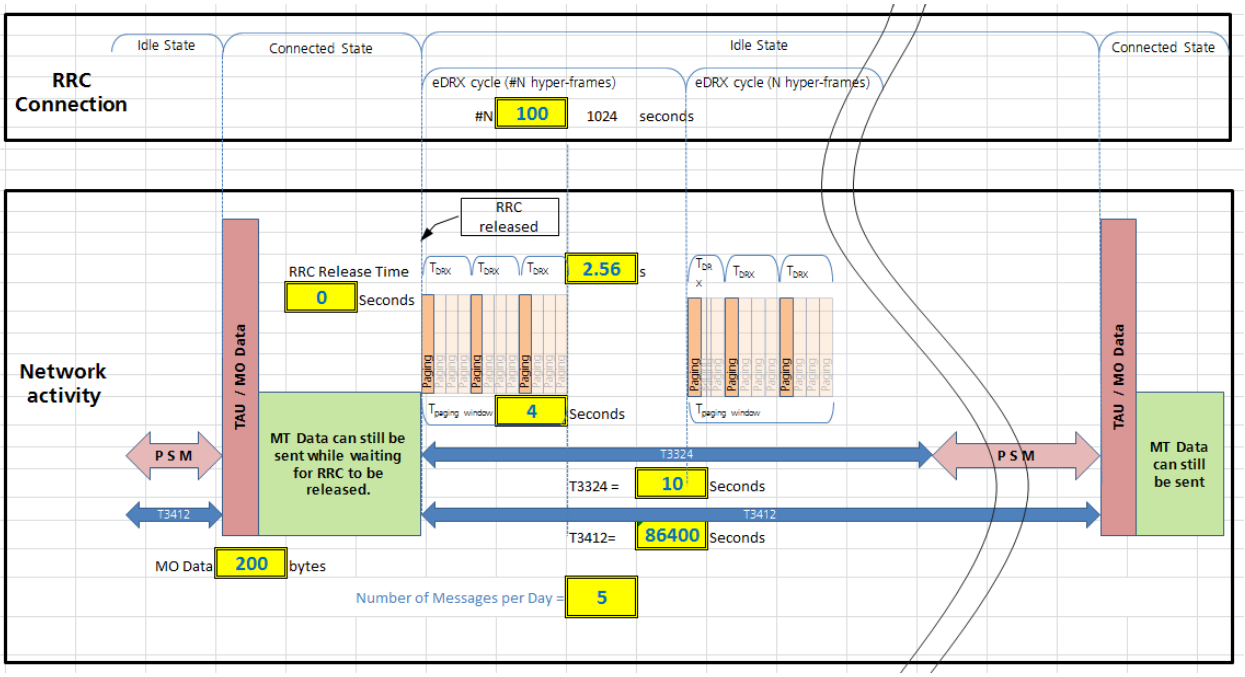
18 Paging, eDRX, PSM and deep sleep mode

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

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

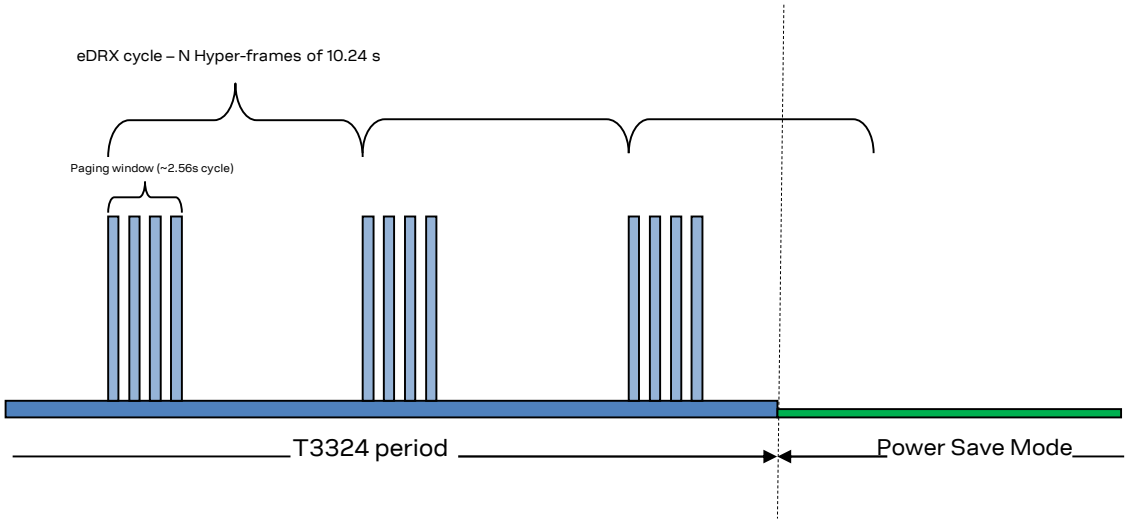
The module enters the deep sleep mode when there is no activity, it does not need to be in the PSM.

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



18.1 eDRX

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



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

☞ If the eDRX state is changed by enabling or disabling eDRX via `+CEDRXS`, a `AT+CFUN=15` or proper shut-down/power-up should be applied for eDRX to properly function.

☞ The application can read the network eDRX value using the `AT+CEDRXRDP` command.

☞ The direct link mode for both sockets and FTP should not be used with HW flow control and eDRX all three combined together. This combination can lead to the module going into eDRX deep sleep during active direct link data transfer session to due potential HW flow control timing leading to data not being able transfer smoothly and connection timeout.

18.2 Power save mode (PSM)

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

☞ When in PSM the module will not respond AT commands.

☞ See sections 18.2.3 and 18.2.4 for how to set T3412 and T3324 values in `+CPSMS` AT command.

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

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

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

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

On the SARA-R4 series modules, the only thing that is retained across PSM cycles is the PDP context. Any PPP connections, sockets, or other connections must be re-established upon exiting the PSM. Since the module is essentially in the off state when it goes into the PSM, the behavior is similar to what would be expected if the module is turned off and turned it back on.

Any settings the host application has made will need to be re-configured again after waking up the module. For example, `ATE0`, `AT&S0`, `AT+CMEE`, `AT+CEREG`. Only commands that state in the AT commands manual they are saved in Non-Volatile Memory are kept in PSM.

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

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

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

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

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

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

18.2.1 PSM with no customized timer request

Command	Response	Description
`AT+CMEE=2`	`OK`	Enabling the verbose error.
`AT+CPIN="1234"`	`OK`	Activating the SIM card. ☞ The SIM card needs to be active to enter the PSM.
`AT+COPS?`	`+COPS: 0,0,"Verizon Wireless",7` `OK`	Confirming the module has been registered with the current carrier.
`AT+CPSMS=1`	`OK`	The module is turning on the PSM. The request sent in the TAU message only contains default values for the timers.
`AT+CFUN=15`	`OK`	Reboot to enable the PSM.
`AT+UCPSMS?`	`+UCPSMS: 1,,,"00011100","00001010"` `OK`	Querying the returned values. • 00011100: 280 minutes (4 hr 40 min) for TAU • 00001010: 20 s for active timer.

18.2.2 PSM with customized timer request

Command	Response	Description
AT+CMEE=2	OK	Enabling the verbose error.
AT+CPIN="1234"	OK	Activating the SIM card. ☞ The SIM card needs to be active to enter the PSM.
AT+COPS?	+COPS: 0,0,"Verizon Wireless",7 OK	Confirming the module has been registered with the current carrier.
AT+CPSMS=1,,,"00011101","00001010 1"	OK	Enabling the PSM. Requesting customized timers.
AT+CFUN=15	OK	Reboot to enable the PSM.
AT+UCPSMS?	+UCPSMS: 1,,,"00011111","00001011" OK	Querying the returned values. • 00011111: 310 minutes (5 hr 10 min) for TAU • 00001011: 22 s for active timer

18.2.3 T3412 timer (Periodic TAU)

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

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

Example: "**010**00111" = 7 **x10 hours** = 70 hours

☞ To allow the PSM to correctly function and allow the module to wake up for a TAU, the minimum recommended T3412 timer is 90 s.

☞ NOTE 1: This timer value unit is only applicable to the T3312 extended value IE and the T3412 extended value IE (see 3GPP TS 24.301 [9]). If it is received in an integrity protected message, the value shall be interpreted as multiples of 320 hours. Otherwise, the value shall be interpreted as multiples of 1 hour.

☞ NOTE 2: This timer value unit is not applicable to the T3412 extended value IE. If this timer value is received, the T3412 extended value IE shall be considered as not included in the message (see 3GPP TS 24.301 [9]).

18.2.4 T3324 timer (Active Time)

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

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

Example: "**001**00100" = 4 **x1 minute** = 4 minutes

18.2.5 PSM indication

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

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

18.2.6 Power save mode when there is no network

SARA-R4 modules will enter the Power Save Mode if the PSM is enabled (+CPSMS) and cannot find a network to register on. Because the module has been configured to be power efficient with PSM, if the module fails to find a network it will go still into PSM.

18.2.7 Toggling PSM

If the PSM is enabled upon boot, then it can be toggled off and back on by means of the +CPSMS AT command without rebooting/reset. Toggling is helpful in cases where the host does not want the module to go into PSM during tasks that may have idle periods that can permit the device to go into PSM.

If the PSM is not enabled upon boot, then it cannot be toggled without rebooting or reset.

18.2.8 PSM and roaming

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

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

19 Application design for low power

19.1 Static applications

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

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

19.1.1 Battery powered

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

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

19.1.2 Mains powered

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

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

19.2 Mobile applications

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

20 GNSS

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

20.1 Power control

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

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

21 Testing

21.1 End user test (+UTEST)

Table 1 provides the list of pins that can be tested by means of the AT+UTEST=10 command. The command allows the user to perform some verifications on all the digital pins of the SARA-R4 series modules.

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

Table 1: SARA-R4 pins for +UTEST=10 testing

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

Command	Response	Description
		Configure the formatting of the error result code by means of +CMEE AT command.
`AT+COPS=2`	`OK`	Deregister the module from the network.
`AT+UTEST=1`	`OK`	The module enters the test mode.
`AT+UTEST=10,1`	`(pin description returned)` `OK`	Gets the pin information.
`AT+UTEST=10,2,"000000000000000000008000"`	`OK`	Put the module in interface initialized state; the command saves the pins status to

Command	Response	Description
		restore it at the end of the test. Pins enabled for testing: GPIO1 pin 16 Where hex: 0000 0000 0000 0000 0000 8000
AT+UTEST=10,3,"000000000000000000000000"	OK	GPIO1 is configured for output where the bits for pin 16 are set low Where hex: 0000 0000 0000 0000 0000 0000
AT+UTEST=10,4,"000000000000000000008000"	OK	GPIO1 is set to high for pin 16 Where hex: 0000 0000 0000 0000 0000 8000
AT+UTEST=10,5		Configurations made by AT+UTEST=10,2; AT+UTEST=10,3 and AT+UTEST=10,4 are executed.
AT+UTEST=10,6	000000000000000000008000 OK	Logic digital value measured at modules pins for GPIO1, and "high" level detected.

Below is an example of configuring RTS and CTS as output and set to high. This example can only be done through the USB interface.

Command	Response	Description
		Configure the formatting of the error result code by means of +CMEE AT command.
AT+COPS=2	OK	Deregister the module from the network.
AT+UTEST=1	OK	The module enters the test mode.
AT+UTEST=10,1	(pin description returned) OK	Gets the pin information.
AT+UTEST=10,2,"000000000000000000000600"	OK	The command puts the module in Interface initialized state; the command saves the pins status to restore it at the end of the test. Pins enabled for testing: RTS pin 10, CTS pin 11 Where hex: 0000 0000 0000 0000 0000 0600
AT+UTEST=10,3,"000000000000000000000000"	OK	RTS and CTS are configured for output where the bits for the pins 10,11 are set low Where hex: 0000 0000 0000 0000 0000 0000
AT+UTEST=10,4,"000000000000000000000600"	OK	RTS and CTS is set to high for pin 10, 11 Where hex: 0000 0000 0000 0000 0000 8000
AT+UTEST=10,5		Configurations made by AT+UTEST=10,2; AT+UTEST=10,3 and AT+UTEST=10,4 are executed.
AT+UTEST=10,6	000000000000000000000600 OK	Logic digital value measured at modules pins for GPIO1, and "high" level detected.

- When a SARA-R4 series module is programmed to enter the end user test mode, the `+CFUN: 5` URC will be reported if the module is in +UTEST mode, and it can be used as an indication the module does not exit properly the +UTEST mode.
- The usage of this command shall be restricted to controlled (shielded chamber/box) environments and for test purpose only, especially when RF testing.

☞ If +UGPIOC, +UGPIOR, and +UGPIOW AT commands are used in the same power-up session, then apply these commands before applying the AT+UTEST=10 command. This will allow AT+UTEST=10 to interact with the pins effectively, and not have conflicting control with the other commands.

⚠ u-blox assumes no responsibilities for the inappropriate use of this command.

21.1.1 Entering and exiting the RF non-signaling mode

For a brand-new factory device, to enter the non-signaling mode for the first time it is suggested a reset to be performed after the first AT+UTEST=1 command is issued.

Example of entering the non-signaling mode:

Command	Response	Description
AT+UTEST?	+UTEST: 0 OK	Check the device is in signaling mode.
AT+UTEST=1	OK	Enter the non-signaling mode.
AT+CFUN=15	OK	Perform a reset.
AT+UTEST=1	OK	Enter the non-signaling mode again.
AT+UTEST?	+UTEST: 1 OK	Check the UTEST is in non-signaling mode.
AT+CFUN?	+CFUN: 5 OK	Check +CFUN is 5 to ensure the module is in Factory Test mode. The device is now ready for either TX, RX non- signaling tests.
AT+UTEST=3,123130,23,,,5000	+UTEST: 123130,23,5,1,5000 OK	Example 1: TX test executed on B12 TX, Ch. 123130, 23 dBm, TX output for 5 s.
AT+UTEST=2,105060,5000	+UTEST: 105060,5000,0,-21,-20,-19 OK	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.

For any module (factory brand new or not) when exiting the non-signaling mode to get back into the signaling mode, it is important to check that the device has properly been restored to signaling mode. This requires a check between +UTEST and +CFUN state to see if they are in agreement.

Example of checking module is properly in signaling mode after it exits +UTEST non-signaling mode:

Command	Response	Description
AT+UTEST?	+UTEST: 0 OK	The device is in non-signaling mode according to UTEST.
AT+CFUN?	+CFUN: 5 OK	The device is not completely in non-signaling mode because +CFUN reports that it is in factory test mode. Below is the sequence to correct this.
AT+CFUN=0	OK	Set the MT to minimum functionality.
AT+CFUN=1	OK	Sets the MT to full functionality.
AT+CFUN?	+CFUN: 1 OK	The device is now set to full functionality.
AT+UTEST?	+UTEST: 0 OK	The device is in signaling mode. Both CFUN and UTEST are in agreement that the device is in signaling mode.

21.1.2 UTEST RF TX non-signaling continuous mode

For TX non-signaling mode, avoid using continuous mode if possible due to internal mode TX flag not getting cleared when transitioning to the next non-signaling test.

If the continuous mode is used, then issue a subsequent non-continuous mode of the same frequency, channel and power output to clear an internal flag.

Example of clearing an internal flag if the continuous mode is used for RF TX non-signaling mode:

Command	Response	Description
AT+UTEST=3,123060,23,,,0	OK	Turn on the continuous TX in B12, Ch. 123060, 23 dBm.
AT+UTEST=3,123060,23,,,1000	+UTEST: 123060,23,5,1,1000 OK	Turn on TX for 1 s in B12, Ch. 123060, 23 dBm This will clear the internal TX flag set by continuous mode.

21.1.3 UTEST RX and TX non-signaling test sequence

☞ It is recommended to perform all RX UTEST grouped sequentially together, separate from the TX UTESTs test grouped sequentially together. This may help avoid measurement glitches.

A glitch is defined as a measurement output of an expected value, but reports a value with a significant differential. Example: if the module were instructed to transmit 20 dBm, but the device actually transmits 0 dBm, and there is no RF connectivity hardware at fault, then this is likely a glitch.

If a glitch should be encountered then a reset (AT+CFUN=15) and re-entry back into UTEST non signaling mode is required to clear the glitch.

A measurement glitch does not occur randomly; it can happen through a combination of TX and RX measurements and is reproducible. Therefore, if a glitch is encountered or not encountered in the development of the UTEST sequence, then it will not unexpectedly change the behavior with the same sequence repeated.

☞ For any UTEST sequence desired, it should be verified with measurements before deploying into production.

Example of grouping TX and RX tests in non-signaling RF mode:

Command	Response	Description
AT+UTEST=3,123060,23,,,5000	+UTEST: 123060,23,5,1,5000 OK	TX test on B12, Ch. 123060, 23 dBm, 5 s on.
AT+UTEST=3,123095,23,,,5000	+UTEST: 123095,23,5,1,5000 OK	TX test on B12, Ch. 123095, 23 dBm, 5 s on.
AT+UTEST=3,120000,23,,,1000	+UTEST: 120000,23,5,1,1000 OK	TX test on B4, Ch. 120000, 23 dBm, 1 s on.
AT+UTEST=3,120100,23,,,1000	+UTEST: 120100,23,5,1,1000 OK	TX test on B4, Ch. 120100, 23 dBm, 1 s on.
AT+UTEST=2,105020,2000	+UTEST: 105020,2000,0,-20,-20,-19 OK	RX test on B12, Ch. 105020, 23 dBm, 2 s on[3].
AT+UTEST=2,105070,2000	+UTEST: 105070,2000,0,-21,-20,-20 OK	RX test on B12, Ch. 105070, 23 dBm, 2 s on[3].
AT+UTEST=2,102000,2000	+UTEST: 102000,2000,0,-21,-20,-20 OK	RX test on B4, Ch. 102000, 23 dBm, 2 s on[3].
AT+UTEST=2,102100,2000	+UTEST: 102350,2000,0,-21,-20,-20 OK	RX test on B4, Ch. 102350, 23 dBm, 2 s on[3].

[3] Use 100 kHz offset from center frequency of RF input signal. For example, to test EARFCN=2525 of LTE B5, corresponding to 881.50 MHz, set the RF frequency of the generator to 881.50 + 0.1 = 881.6 MHz. The modulation setting is not required.

21.2 Testing with network simulators

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

☞ MAC QoS timer is supported by SARA-R4 “02” product versions except for SARA-R410M-02B-00, SARA-R410M-02B-01, SARA-R410M-02B-02, SARA-R410M-52B-00, SARA-R410M-52B-01, SARA-R410M-52B-02, SARA-R412M-02B-00, and SARA-R412M-02B-01.

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

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

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

Another factor to consider with using a test simulator is the need for using a dedicated test SIM. For more details, see section 26.1.

22 Debugging

22.1 Logging port

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

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

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

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

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

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

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

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

23 Migration

23.1 SARA-G3

23.1.1 PDP activation

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

23.1.2 +UPSDA

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

24 SMS

24.1 SMS preferred message storage

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

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

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

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

25 WWAN adapter

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

25.1 Disabling Qualcomm WWAN adapter

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

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

Disable this adapter to log and perform device data calls.

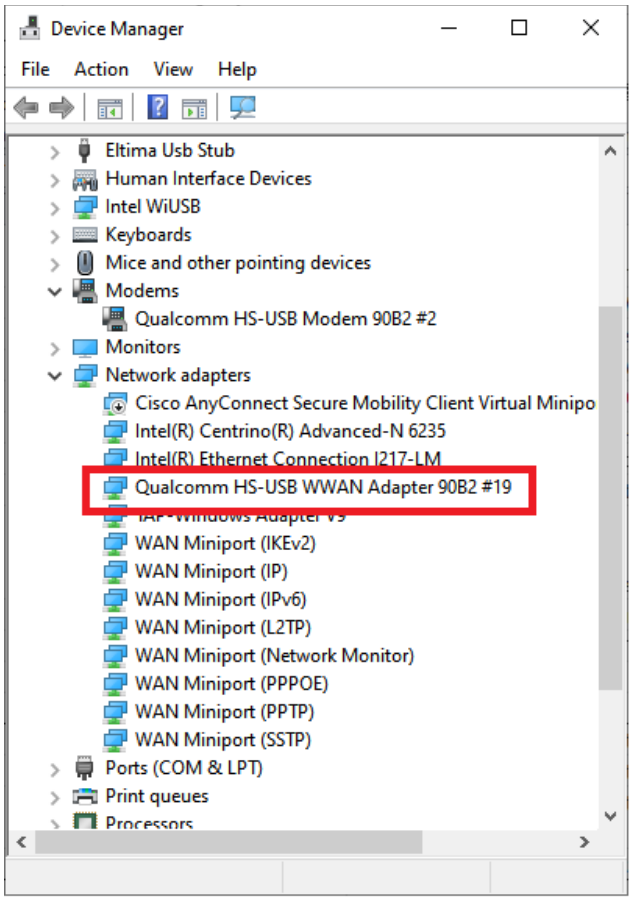


Figure 2: Windows Device Manager: Qualcomm WWAN port that needs to be disabled

26 SIM

26.1 Chip SIM

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

Appendix

A LTE Cat M1 vs NB1

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

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

B Glossary

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

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

Table 2: Explanation of the abbreviations and terms used

C SIM issuer identification number database

Table 3, Table 4, and Table 5 provide the list of SIM issuer identification number (IIN) database. These databases are used when either auto select MNO profile 1 is used or with the IIN detection feature found on SARA-R410M-63B-00.

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

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

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

Table 3: SARA-R410 “63” / “73” / “83” SIM INN values stored on device database used for MNO profile selection

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

Table 4: SARA-R410M and SARA-R412M “02” / “52” product versions SIM IIN values stored on device database used for MNO profile selection (part I)

	Telstra	T-Mobile US	Vodafone	Verizon
SARA-R410M-02-00			894410 8988239 894410	891480 891004 891005 891012 891650 891433 891444 891483 891486 891487 891489 891808
SARA-R410M-52-00				891480 891004 891005 891012
SARA-R410M-52-01 SARA-R410M-52-02				891480 891004 891005 891012

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

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

Related documentation

[1] u-blox SARA-R4 series data sheet, UBX-16024152
[2] u-blox SARA-R4 series AT commands manual, UBX-17003787
[3] u-blox SARA-R4 series system integration manual, UBX-16029218
[4] u-blox SARA-R4 series Firmware update application note, UBX-17049154
[5] u-blox LTE attachment & transport planes presentation, UBX-19006672
[6] u-blox security suite application note, UBX-19030037
[7] 3GPP TS 36.321 Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification
[8] 3GPP TS 24.008 - Annex G (informative): 3GPP specific cause values for mobility management
[9] 3GPP TS 24.301 - Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3
[10] 3GPP TS 27.010 - Terminal Equipment to Mobile Station (TE-MS) multiplexer protocol
[11] RFC 6347 - Datagram transport layer security (DTLS)
[12] RFC 793 - Transmission control protocol (TCP) protocol specification

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

Revision history

Revision	Date	Name	Status / Comments
R01	25-Oct-2018	pwar / clee	Initial release
R02	07-Dec-2018	pwar / clee	Review release
R03	04-Feb-2019	pwar / clee	General release
R04	08-Feb-2019	pafe	Extended document applicability to SARA-N4 series
R05	19-Jun-2019	pwar	Minor updates
R06	30-Sep-2019	skri / clee	Added SMS
R07	27-Jan-2020	clee	Extended document applicability to SARA-R410M "63" / "73" product versions
R08	12-Jun-2020	clee	Extended document applicability to SARA-R410M-83B product version Added disabling WWAN adapter
R09	03-Sep-2020	clee	Minor updates
R10	10-Dec-2020	clee	Minor updates

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