



NB-IoT Application Development Guide

Technology architecture and AT command examples

Application Note



Abstract

This document provides detailed examples of how to use AT commands with u-blox NB-IoT SARA-N2 modules series.

Document Information

Title	NB-IoT Application Development Guide	
Subtitle	Technology architecture and AT command examples	
Document type	Application Note	
Document number	UBX-16017368	
Revision and date	R05	20-Jul-2018
Disclosure Restriction		

This document applies to the following products:

Product name
SARA-N2 series

u-blox or third parties may hold intellectual property rights in the products, names, logos and designs included in this document. Copying, reproduction, modification or disclosure to third parties of this document or any part thereof is only permitted with the express written permission of u-blox.

The information contained herein is provided "as is" and u-blox assumes no liability for its use. No warranty, either express or implied, is given, including but not limited to, with respect to the accuracy, correctness, reliability and fitness for a particular purpose of the information. This document may be revised by u-blox at any time without notice. For the most recent documents, visit www.u-blox.com.

Copyright © u-blox AG.

Contents

Document Information	2
Contents	3
1 Introduction	6
2 NB-IoT technology overview	7
3 AT command response parser	8
3.1 Unsolicited result code.....	8
3.2 Best practices	9
4 Registration with the NB-IoT network	10
4.1 Auto registration.....	10
4.1.1 Configuring auto registration	10
4.2 Manual registration with the NB-IoT network	10
4.2.1 Configuring manual registration	10
4.2.2 Starting registration process, default PLMN/APN.....	10
4.2.3 Starting registration process, specified PLMN/APN	11
4.3 Group hopping with FW version 06.57 A07.03.....	11
5 Base station scanning	12
5.1 Previous PLMN	12
5.2 Home PLMN	12
5.3 Roaming / International SIMs.....	12
5.3.1 With FW 06.57 A07.03.....	12
5.3.2 With later firmware	12
5.3.3 Saving the PLMN	12
6 RRC connection & Release assistance	13
6.1 RRC connection	13
6.2 Release assistance	13
6.3 Current drawn in RRC connected mode	13
7 Paging, eDRX, PSM and Deep Sleep mode	14
7.1 eDRX	14
7.2 Power Save Mode (PSM).....	15
8 Monitoring module status	16
8.1 Registration status	16
8.2 Base station connection (RRC connected state)	16
8.3 Power Save Mode status.....	17
8.4 Connection status matrix	17
8.5 Viewing IP address.....	17
8.6 Checking module statistics	17
9 UDP sockets	19
9.1 Creating a socket	19
9.2 Closing a socket	19
9.3 Sending UDP data.....	19
9.4 Receiving UDP data	19

9.4.1	Data arrived indicator	19
9.4.2	Reading data from socket.....	20
9.5	Testing UDP sockets	20
10	Constrained Application Protocol (CoAP)	21
10.1	CoAP profiles.....	21
10.2	CoAP command.....	21
10.3	CoAP component selection.....	22
10.4	CoAP example	22
10.4.1	Configure the IP address and options in a CoAP profile	22
10.4.2	Select the CoAP component for AT use.....	22
10.4.3	Execute CoAP action	22
11	Non-IP Messaging.....	23
11.1	Connection process	23
11.2	Uplink messaging.....	23
11.3	Downlink messaging	23
11.4	Downlink issue with FW 06.57 A07.03.....	23
12	Operation tests	24
12.1	Band of operation	24
12.2	SIM	24
12.3	Searching for network.....	24
12.4	Registering on the network.....	24
12.5	T3324 and T3412 timers.....	25
12.6	Power save mode.....	25
12.7	Ping	25
12.8	Echo server	25
13	Simple AT command example	26
14	Debugging	27
14.1	Manual debugging with +NUESTATS.....	27
14.1.1	+NUESTATS="RADIO"	27
14.1.2	+NUESTATS="CELL"	27
14.1.3	+NUESTATS="BLER"	27
14.1.4	+NUESTATS="THP"	27
14.2	Manual debugging with URCs	28
14.3	Debug log stream	28
14.3.2	UE Monitor	28
15	Power profile.....	30
15.1	200 bytes, ECL1, without Release Assistance	30
15.2	200 bytes, ECL1, with Release Assistance	30
15.3	Uplink allocations based on SNR	31
15.3.1	Good SNR, coverage Class 2.....	31
15.3.2	Bad SNR, coverage Class 2	31
16	Design for reduced power consumption	32
16.1	Hardware design	32
16.2	Release Assistance.....	32

16.3 PSM and eDRX.....	32
16.4 Minimizing coverage Level 2.....	32
17 Network architecture mapping on AT commands	33
18 NB-IoT best practices.....	34
18.1 Radio and network status polling.....	34
18.2 Deep-sleep mode.....	34
18.3 Message size.....	34
18.4 Message buffer	34
18.5 Application architecture.....	34
19 FOTA	36
19.1 Server.....	36
19.2 Configuration	36
19.3 Status.....	36
19.4 Package download query.....	36
19.5 Example.....	37
20 End user test (+UTEST)	38
20.1 Enabling / Disabling the end user test.....	38
20.2 Rx tests	38
20.3 Tx tests	38
21 Datagram messages with Huawei OceanConnect IoT platform.....	39
21.1 Sending MO datagrams.....	39
21.2 Querying MO datagram sent status	40
21.3 Receiving MT datagrams	40
21.4 Querying MT datagram received status	40
21.5 Avoiding data loss.....	40
21.6 Send message indication +NSMI.....	41
21.7 New message indications +NNMI.....	41
Appendix	43
Related documents	46
Revision history	46
Contact.....	47

1 Introduction

This document provides guidance when developing applications for NB-IoT. It includes examples of using AT commands used to communicate with the u-blox NB-IoT modules and how to send UDP packets. See the SARA-N2 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 NB-IoT technology overview

NB-IoT technology is designed such that it can be used in areas beyond the radio coverage of current cellular standards and in devices which must run from battery power for many years. The devices will generally send small amounts of data infrequently; a typical usage scenario might be 100 to 200 bytes sent twice per day for battery powered devices. For mains powered devices the limit is not based on battery size, but cost and network bandwidth/resources.

The system operation is analogous to SMS in that it is a datagram-oriented, stored-and-forward system, rather than a GPRS-like IP pipe. This is because NB-IoT devices spend most of their time asleep, making possible the required long battery life. The system implements extended DRX cycles for paging, but as this window will be limited to save battery life, the delivery of downlink messages occurs mainly when the system detects that uplink messages have been received from a device (indicating that it is awake). Here a store-and-forward system, an “IoT Platform”, is useful.

A simplified system is represented in [Figure 1](#).

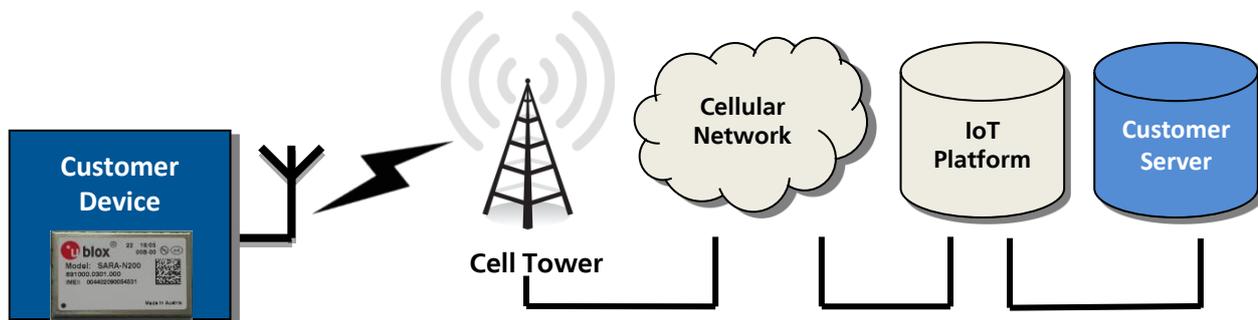


Figure 1: NB-IoT system architecture

At the far left the customer’s device contains a u-blox NB-IoT module that communicates over the radio network with a cell tower that supports the NB-IoT network. The cellular network links the cell tower with an IoT platform. This IoT platform stores uplink datagrams from the NB-IoT module. The customer server communicates with the IoT platform to retrieve uplink datagrams and to send downlink datagrams to the NB-IoT. The IoT platform holds downlink datagrams until the NB-IoT module is awake to receive them.

The SARA-N2 series modules implement basic UDP socket commands for directly communicating with an external service. With these commands the customer can build a simple IoT platform. With an external processor other IoT layers could be implemented to aid this system design. SARA-N2 series modules support AT commands for general CoAP messaging. This allows the customer to not require CoAP in their external processor.

3 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 NB-IoT 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 result code.

3.1 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. The implemented URCs are as follows:

- | | |
|---|-------------------------|
| • <code>+CEREG: <stat>[,<tac>,<ci>,<AcT>]</code> | Network registration |
| • <code>+NPING: <retry_num>,<remote_address>,<ttl>,<rtt></code> | Ping |
| • <code>+NSONMI: <socket>,<length></code> | Received data on socket |
| • <code>+NNMI: <length>,<data></code> | New message indicator |
| • <code>+NNMI</code> | New message indicator |
| • <code>+NSMI: SENT</code> | Sent message indicator |

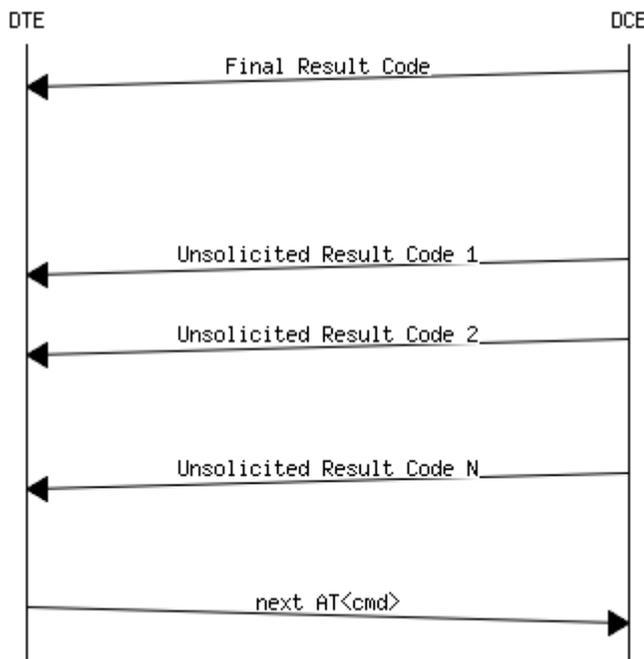


Figure 2: DTE-DCE URC flow chart

3.2 Best practices

- The DTE shall flush the AT channel (i.e. check if there is data waiting to be read) before sending a new AT command.
- The DTE shall handle the case of unexpected spaces or line endings.
- The DTE shall handle all the URCs: it can simply ignore them (not suggested) or, better, take a proper action.
- The DTE shall know what answer is expected and shall 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-N2 AT Command 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.

4 Registration with the NB-IoT network

Before the customer's application can send or receive any messages to their cloud server the module must first register on the NB-IoT network. The SARA-N2 series modules have two options for registration, auto or manual.

After the registration process has started, it is possible to query the status using the +CEREG read command, or by configuring the +CSCON URC.

4.1 Auto registration

By default the SARA-N2 series modules will automatically try and connect to the network. This feature will read the SIM for the PLMN and attempt to register with the network. The device will use the default APN from the network. The auto-connect feature can be enabled by the +NCONFIG AT command. Reset the module to save these settings to the non-volatile memory.

4.1.1 Configuring auto registration

Command	Response	Description
AT+NCONFIG="AUTOCONNECT", "TRUE"	OK	Enable the AUTOCONNECT feature.
AT+NRB		Reset the module to save this setting.

4.2 Manual registration with the NB-IoT network

If the application requires more control over the registration process set the SARA-N2 series modules into the manual registration mode. With the auto-connect feature turned off the module is able to manually connect to a specific PLMN and specify an APN.

4.2.1 Configuring manual registration

The auto-connect feature is by default disabled by the +NCONFIG AT command. Reboot the module to save these settings to non-volatile memory.

Command	Response	Description
AT+NCONFIG="AUTOCONNECT", "FALSE"	OK	Disable the AUTOCONNECT feature.
AT+NRB		Reset the module to save this setting.

4.2.2 Starting registration process, default PLMN/APN

Command	Response	Description
AT+CFUN=1	OK	Turn on the module's radio functionality.
AT+CGATT=1	OK	Start the registration process and attach to the packet switched data services. This will read the PLMN from the attached SIM.
		The network will provide the APN to the module.

 The +CGATT AT command creates a context ID starting from zero (0).

4.2.3 Starting registration process, specified PLMN/APN

Command	Response	Description
AT+CFUN=1	OK	Turn on the module's radio functionality.
AT+CGDCONT=<cid>,"IP","APN_Name"	OK	Configure the APN (if required).
AT+COPS=1,2,"12345"	OK	Start the registration process with specifying a PLMN.



Do not use the AT+CGATT command when using AT+COPS or AT+CGDCONT as it will revert the specified PLMN/APN back to the default value.

4.3 Group hopping with FW version 06.57 A07.03

There is a known issue with FW version 06.57 A07.03: the module does not connect to a network if the Group Hopping feature has been enabled. For more details on Group hopping feature, see 3GPP TS 36.331 [6], section 10.1.4.1.3.

5 Base station scanning

When the module starts the registration process it must first scan for a base station based on the PLMN of the SIM. This scanning process is different depending if there is a previous stored PLMN, the SIM is for the home network or if it is a roaming/international SIM.

5.1 Previous PLMN

If the module has previously camped on a cell, the PLMN will have been stored in the SIM. It will try to use the previous PLMN when the module first turns on. If this fails it will then try the Home PLMN.

5.2 Home PLMN

The module will try to camp on the HPLMN stored in the SIM. In the quick cell search after the module power-on, once the PLMN is found it will start to register on that cell. If this fails it will then try the Roaming processes.

5.3 Roaming / International SIMs

There is a different cell scanning process depending if the SIM is a Home SIM or Global SIM.

5.3.1 With FW 06.57 A07.03

If a roaming PLMN is being used, the module will perform a deep cell search of all supported bands before trying to register on a cell using the RPLMN. This process is a deep search so that even weak signaled cells can be found in PLMN selection. This can take over ten minutes or more depending on the number of LTE bands supported by the module.

Because cell selection with home SIMs takes less than 2 minute normally, it might be best to try automatic connection for 2 minutes, and then try a manual connection using `AT+COPS=1, 2, "<PLMN>"` – if a list of known PLMNs is available.

 There are no AT commands that will provide the indication about the Home or Roaming SIM.

5.3.2 With later firmware

A new firmware that resolves this issue will be released Q3 2018. Cell scanning times will be very similar to home SIMs.

5.3.3 Saving the PLMN

Once registered the PLMN will be saved to the module so that when the module is turned on or rebooted the long deep scan will not need to be performed again.

6 RRC connection & Release assistance

6.1 RRC connection

At the first registration or when the module wakes from the power save mode (PSM), it performs a Random Access CHannel (RACH) procedure to attach to the base station. This establishes a Radio Resource Control (RRC) connection to the base station. Once established only the base station can release this connection. The module cannot drop the RRC connection other than turning off the radio using the `AT+CFUN=0` command.

The base station has an “inactivity” timer for each module and if there is no activity the base station will send a RRC release message to the module. The module should respond back to the base station with an acknowledgment. The inactivity timer is nominally 20 s.

The module will be able to receive and send messages immediately when in connected mode.

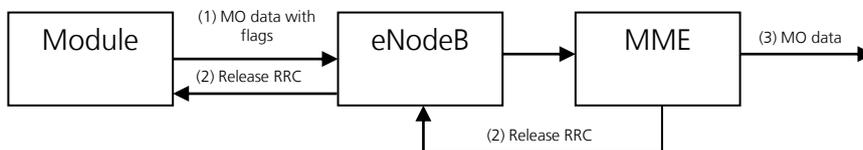
During a RRC connection, the `+CSCON` AT command provide the signalling connection status. It is also possible to enable the `+CSCON` URC.

6.2 Release assistance

Some applications may not want to wait for the base station’s inactivity timer to expire after 20 s as this wastes power from the battery. In Release-13 the “Release Assistance” feature allows the module to request for the RRC connection to be dropped as soon as the message has been received by the network.

See the `+NSOSTF` AT command to configure the Release Assistance feature.

The flag is noticed by the MME on the network and sends a message back to the eNodeB base station to drop the RRC connection. The network must support Release Assistance for this feature.



After the RRC connection has been released the module then goes in to a period where it could be paging the base station. The timer for this period is called T3324. After T3324 has expired the module goes into Power Save Mode (PSM). See section 11 for further information

6.3 Current drawn in RRC connected mode

When the module is in RRC connected mode it will be receiving all the base station signaling. The average power consumed in this mode is about 48 mA. If the RRC connection is left for 20 s of inactivity before the RRC is released, then this will consume about 1 mWh @ 3.6V.

Without the Release Assistance feature the power consumption will be at least 1 mWh for every message sent.

7 Paging, eDRX, PSM and Deep Sleep mode

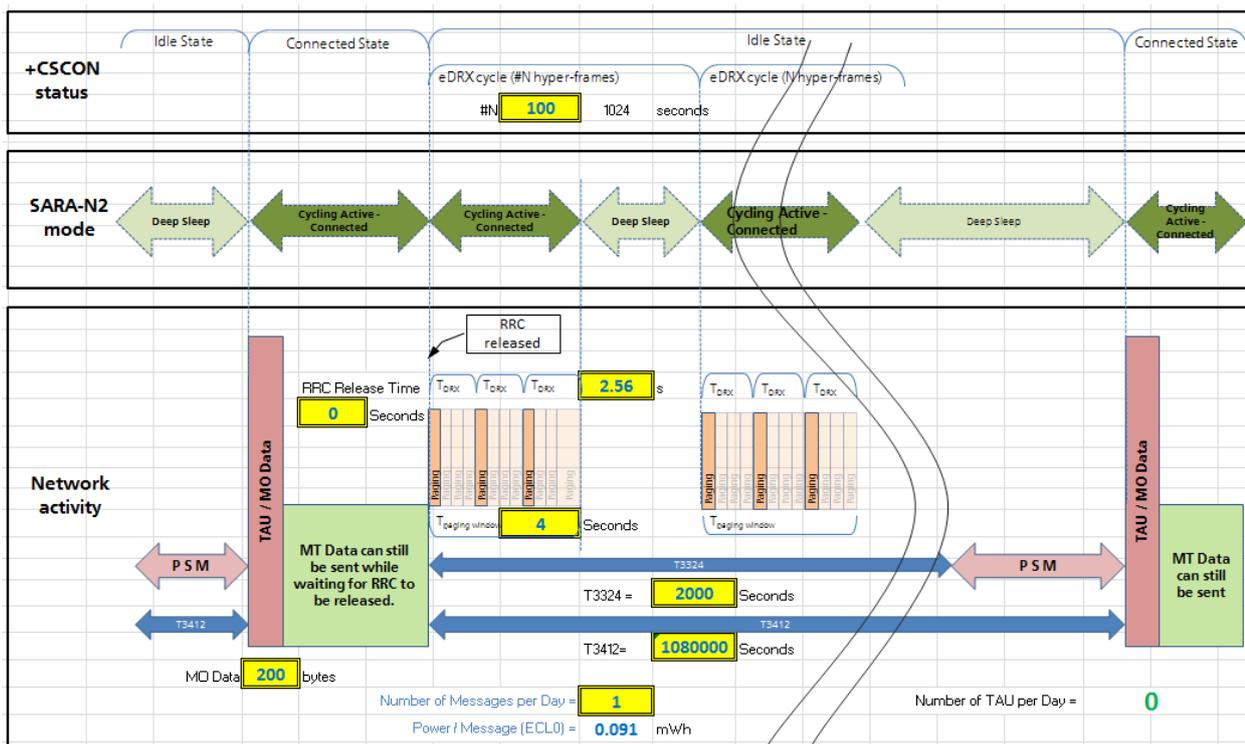
The NB-IoT protocol allows for power save mode (PSM), and the SARA-N2 series modules also support a Deep Sleep mode where the module is running at very low current, $\sim 3 \mu\text{A}$. The module automatically enters various states depending on the device activity. Here below are listed the common activities and the various states it will be in after registration.

1. The device is in **Power Save Mode (PSM)** and in **Deep Sleep**; it is already registered and there is no activity.
2. A message is queued or the TAU timer has elapsed.
3. The device re-connects to the 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, the 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.

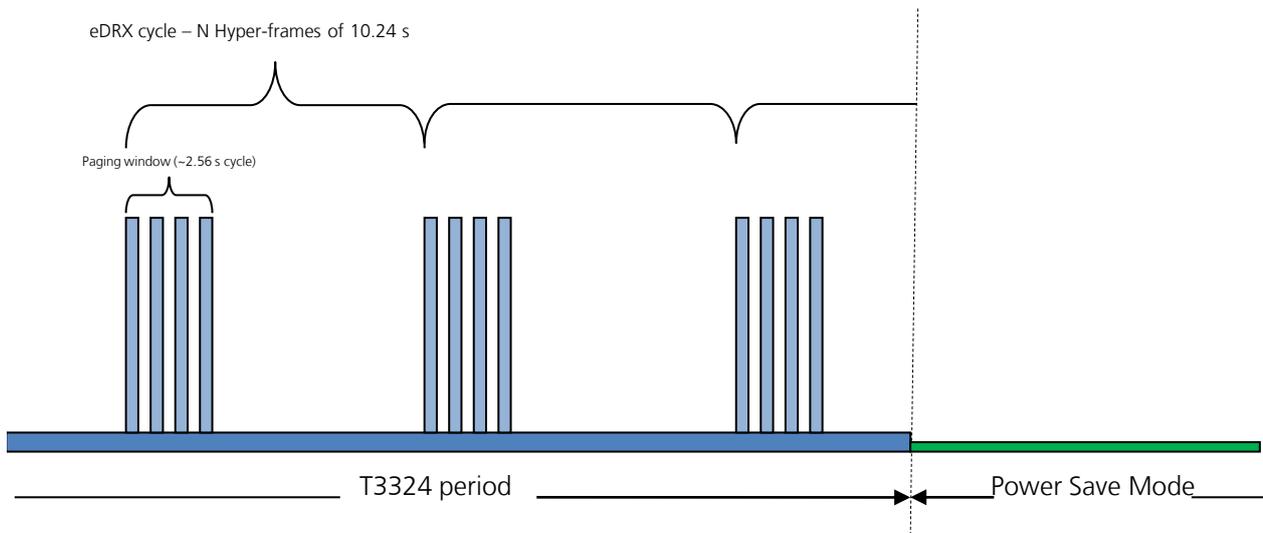
Taken from the Power Consumption Spreadsheet:



7.1 eDRX

The 3GPP specification Rel. 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 a number of hyperframes (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 awaken for the next paging window after the eDRX cycle has completed.

The application can query the network the eDRX value using the `AT+CEDRXS` command.

7.2 Power Save Mode (PSM)

After the T3324 timer expires the module will enter the Power Save Mode. Here the module is in deep sleep mode and is only consuming approximately $3 \mu\text{A}$.

In the PSM the module is not able to receive any downlink messages. If the customer's cloud application tries to send a downlink message to the module when it is in PSM, the network will ignore it.

When in the PSM the module will still respond AT commands and the application does not need to toggle any power or reset lines on the module.

Use the `+NPSMR` AT command to query the PSM status.

Enable the `+NPSMR` URC for the PSM status, otherwise only the URC state will be returned.

8 Monitoring module status

The application can monitor the status of the module's connection, registration and PSM state by polling or configuring URCs. By monitoring the module status the application can behave more efficiently, depending on the application type. For example, the application may want to know when the module goes into Power Save Mode (PSM).

8.1 Registration status

Register the module to the NB-IoT network before to send or receive any messages. Without being registered the module will not be able to send or receive any messages.

To check the network registration status issue the +CEREG read command. The second parameter of the information text response (+CEREG: <mode>,<state>) provides the interested information

- 0: not registered, not registering
- 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 so that registration is quicker next time. The application can tell if it is using roaming SIM by the state being "5".

The +CEREG URC can be enabled to provide the network registration status. Depending on the <mode> parameter it is possible to configure the interested URC parameters (i.e. <mode>=4 or 5 to see the provided network timers). See SARA-N2 AT Commands Manual [2] for more details.



Properly setting the +CEREG AT command (<modem>=3, 4 or 5) it is possible to see the registration EMM cause value. These values are described in the 3GPP TS 24.008 [4]. 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

8.2 Base station connection (RRC connected state)

When a MO message is sent from the module, the module must first create a RRC connection if there is not already established with the base station. This status can be checked using the AT+CSCON command.

To check the signalling connection status issue the +CSCON read command. The second parameter of the information text response (+CSCON: <n>,<state>) provides the interested information:

- 0: idle mode (no RRC connection)
- 1: connected mode (RRC connection)

To configure a URC for this command, issue the AT+CSCON=1 command. A URC will be issued at each RRC connection status change.

8.3 Power Save Mode status

The module implements the Power Save Mode (PSM) where it goes in to a “Deep Sleep” operation consuming 3 μ A. It enters the PSM after the T3324 timer expires. It is possible to query the value of the T3324 timer with the +CEREG read command.

To check the PSM status issue the +NPSMR read command. The second parameter of the information text response (+NPSMR: <n>[,<mode>]) provides the interested information:

- 0: connected or idle mode
- 1: Power Save Mode

Enable the +NPSMR URC for the PSM state to be returned, otherwise only the URC state will be returned.

To configure a URC for this command, issue the AT+NPSMR=1 command. When the module’s PSM status changes, a URC is issued.

8.4 Connection status matrix

Table 1 provides an overview of the AT command described in the previous sections and their values according with the module status:

+CEREG	+CSCON	+NPSMR	Status
0	0	0	Module is on, but not performing any network activity
2	0	0	Module scanning for base station
2	1	0	Module starting registration process, RRC connected mode
1 or 5	1	0	Module registered, RRC connected mode
1 or 5	0	0	Module registered, RRC released, inside T3324 Period (paging/eDRX)
1 or 5	0	1	Module registered, in Power Save Mode
3	-	-	Registration failed

Table 1: connection status compatibility matrix

8.5 Viewing IP address

Before sending any IP data to the NB-IoT network configure the device with an IP address.

Use the +CGPADDR AT command to query 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 address is displayed until the module has registered to 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.

8.6 Checking module statistics

When the module is synchronized to the base station and is receiving the signaling the +NUESTATS AT command is able to describe the radio, cell, BLER and throughput statistics.

The most useful statistic is the "RADIO" type.

Command	Response	Description
AT+NUESTATS="RADIO"	Signal power: number Total power: number TX power: number TX time: number RX time: number Cell ID: number ECL: number SNR: last snr value EARFCN: last earfcn value PCI: last pci value RSRQ: last RSRQ value OK	The information text response indicates the module condition and its environment. The values may be useful for monitoring purposes.

- **Signal power:** it is the power of the wanted part of the receive signal, the NB-IoT part.
- **Total power:** it is the radio signal strength within the receive bandwidth (both expressed in 10ths of a decibel). From this the signal to noise ratio can be calculated.
- **Transmit power:** it is the RF power output from the module. It may be a low number if the received signal strength is good (and hence the module assumes that the base station is close by).
- **Tx time:** it is the duration for which the module's transmitter has been switched on.
- **Rx time:** it is the duration for which the module's receiver has been monitored for downlink activity (both expressed in milliseconds since the last reboot). Together these can be used to assess the time the module spends in each state and hence estimate the power consumed by the module.
- **Cell ID:** it is the physical cell ID of the cell that is currently providing service to the module.
- **ECL:** it is equivalent to "PRACH coverage enhancement level" defined in 3GPP 36.321 [3] sub clause 5.1



There are other statistics available too, for cell, BLER and throughput.

- AT+NUESTATS="CELL"
- AT+NUESTATS="BLER"
- AT+NUESTATS="THP"

See section [14.1](#) for further information about how to use the +NUESTATS AT command to help the module debug.

See SARA-N2 AT commands Manual [\[2\]](#) for further information on +NUESTATS.

9 UDP sockets

The SARA-N2 series modules are able to send raw data through UDP sockets to an IP address. The data sent over the socket AT commands is not wrapped in any other layer, and the data provided is the data that is sent.

9.1 Creating a socket

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

Command	Response	Description
AT+NSOCR="DGRAM",17,<localport>	<socketID> OK	Create a socket with a listening port. Returns the socket ID to be used with other socket commands.

9.2 Closing a socket

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

Command	Response	Description
AT+NSOCL=<socketID>	OK	Specify the socket ID to close.

9.3 Sending UDP 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 is 512 bytes.

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

9.4 Receiving UDP 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.

9.4.1 Data arrived indicator

Command	Response	Description
	+NSONMI:<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.

9.4.2 Reading data from socket

The data reception is performed by means of the +NSORF AT command, using the information given in the +NSONMI URC.

Command	Response	Description
AT+NSORF:<socketId>,<length>	<socket>,<ip_addr>,<port>,<length>,<data>,<remaining> OK	Provides the received data to the application and shows how much data is still left to read out.

9.5 Testing UDP sockets

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.

Here is an example:

Command	Response	Description
AT+NSOCR="DGRAM",17,14000	1 OK	Create a socket. The socket ID is 1. Ready for next AT command.
AT+NSOST=1,"195.34.89.241",7,5,"48656c6c6c6c6c6c"	1,5 OK	Send "Hello" to u-blox echo server. Sent 5 bytes on socket ID 1.
	+NSONMI:1,5	Received 5 bytes on socket ID 1
AT+NSORF=1,5	1,195.34.89.241,7,5,"48656c6c6c6c6c6c",0 OK	Read 5 bytes on socket ID 1. Received data information provided..."Hello".

10 Constrained Application Protocol (CoAP)

The Constrained Application Protocol (CoAP) is a datagram-based client/server application protocol for devices on the constrained network (e.g. low overhead, low-power), designed to easily translate to HTTP for simplified integration with the web. CoAP clients can use the GET, PUT, POST and DELETE methods using requests and responses with a CoAP server.

10.1 CoAP profiles

Configure the CoAP client contained within the module via the one of the four profiles. It is possible to store up to four profiles in the module and select between them. Only one profile can be used at a time.

The profiles are configured, stored and retrieved by setting parameter/value pairs by means of the +UCOAP AT command and its <op_code> parameter that can assume these values:

- 0: server IP address
- 1: URI
- 2: PDU option mask configuration (option to be added in PDU header)
- 3: current profile number (0 to 3)
- 4: valid flag
- 5: restore profile from NVM
- 6: store profile to NVM
- 7: read all profiles

10.2 CoAP command

Issue the +UCOAPC AT command to trigger a CoAP action. The +UCOAPCD URC indicates if sending the command request to the COAP process was successful or not.

It is possible to send data with the CoAP command and identifier. The allowed CoAP actions are:

- 1: GET (data and identifier parameters not allowed)
- 2: DELETE (data and identifier parameters not allowed)
- 3: PUT
- 4: POST



GET, PUT and POST actions accept block operations.

Data included in the PUT or POST actions is in hexadecimal format. Supported identifiers:

- 0: text / plain
- 1: application / link format
- 2: application / xml
- 3: application / octet format
- 4: application / rdf xml
- 5: application / exi
- 6: application / json
- 7: application / cbor

10.3 CoAP component selection

Because the internal CoAP library is shared with other components in the module, select the right CoAP component before use. The component can be selected using the +USELCP AT command. The allowed components are:

- **0 (CDP-MNO)**: confirmable and non-confirmable messages are supported
- **1 (CoAP-AT)**: it can be used to send or receive confirmable messages (by means of the +UCOAPC AT command) via CoAP over the NB-IoT platform. Only confirmable messages are supported
- **2 (FOTA)**: the Firmware Over The Air (FOTA) component uses the CoAP context to download a FW update package from a dedicated FOTA server. For more details see section 19. Only confirmable messages are supported.
- **3 (SELF-REG)**: The self-registration component will access to the CoAP context only at the module boot time. After that, the CoAP context shall be available as mutually exclusive between other components. Only confirmable messages are supported

Before selecting the CoAP component, first configure and active a CoAP profile by means of the +UCOAP AT command.

10.4 CoAP example

This example sends a CoAP message to a CoAP server. First we configure a profile, then select the CoAP operating mode, and then execute a CoAP action.

10.4.1 Configure the IP address and options in a CoAP profile

Command	Response	Description
AT+UCOAP=0, "134.102.218.18", "5683"	OK	Configure the IP address.
AT+UCOAP=1, "coap://coap.me:5683/sink"	OK	Configure the URI of a CoAP resource.
AT+UCOAP=2, "4", "1"	OK	Set the "Content Format" option in the PDU.
AT+UCOAP=2, "0", "1"	OK	Set the "HOST" option in the PDU.
AT+UCOAP=2, "1", "1"	OK	Set the "PORT" option in the PDU.
AT+UCOAP=2, "2", "1"	OK	Set the "PATH" option in the PDU.
AT+UCOAP=4, "0"	OK	Enable profile 0.
AT+UCOAP=6, "0"	OK	Save profile 0.
AT+UCOAP=7, "0"	OK	Read and use profile 0.

Always save and restore the profile before to use it. As shown in the above example:
AT+UCOAP=6, "0"; +UCOAP=7, "0".

10.4.2 Select the CoAP component for AT use

Command	Response	Description
AT+USELCP=1	OK	Select the CoAP-AT mode.

10.4.3 Execute CoAP action

Command	Response	Description
AT+UCOAPC=3, "48656C6C6F20576F726C64", 0	OK	Execute the CoAP PUT action with "Hello World".
	+UCOAPCD: 3, "..."	Result from the CoAP server.

11 Non-IP Messaging

The usage of the Non-IP method during the sending or receiving of 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. For devices in the extreme coverage class 2, this can be quite costly.

When using Non-IP messaging, the Mobile Network Operator shall provide access to the messages since they are stored by it (there is no destination IP address or port).

11.1 Connection process

Command	Response	Description
AT+CDGCONT=<cid>,"NONIP","nonip"	OK	Create a PDP context with type "NONIP" to connect to the network for Non-IP message.
AT+CGATT=1	OK	
AT+NCONFIG="AUTOCONNECT","FALSE"	OK	Disable the AutoConnect feature as this will automatically connect to the network without Non-IP.
AT+NRB		Reboot the module to store and take effect.

11.2 Uplink messaging

Command	Response	Description
AT+CSODCP=<cid>,<length>,"<data>"	OK	Issue the +CSODCP AT command to send an uplink message for Non-IP.
AT+CSODCP=<cid>,<length>,"<data>",<RAI>	OK	It is possible to release assistance, just like with UDP messaging (where <RAI> is 0, 1 or 2)

11.3 Downlink messaging

Command	Response	Description
AT+CRTDCP=1	OK	Turn on the +CRTDCP URC to receive downlink messages.
	+CRTDCP:<cid>,<length>,"<data>"	When the module receives a downlink message, the +CRTDCP URC is issued.

11.4 Downlink issue with FW 06.57 A07.03

There is an issue with Non-IP downlink messaging in A07.03 firmware. Only one downlink message will be emitted. To work around this issue, delete the PDP context after receiving the first downlink message and then re-create it.

- 1. Create a Non-IP context.
- 2. Receive one Non-IP data at downlink with a URC.
- 3. Delete the context.
- 4. Repeat steps 1-3.

12 Operation tests

Some tests and checks can be performed when using a new network. These can help diagnose what network settings are configured and how the module will operate.

12.1 Band of operation

Use the +NBAND AT command to verify if the module is configured for the correct band of operation.

- Band 8 = 900 MHz
- Band 20 = 800 MHz
- Band 28 = 700 MHz
- Band 5 = 850 MHz

12.2 SIM

After the module power-on, if the AUTOCONNECT feature is enabled (see +NCONFIG AT command), then the module will automatically start the radio (equivalent to AT+CFUN=1 command) and read the SIM PLMN.

If the module has the AUTOCONNECT disabled, then turn the radio on first with the AT+CFUN=1 command. This will read the PLMN from the SIM and then return the "OK" final result code. If there is a problem in reading the SIM, the +CFUN AT command will return an error result code and AT+CIMI will not return any IMSI value from the SIM.

The IMSI can be queried by using the AT+CIMI command. Make sure about the correctness of the SIM IMSI.

If there is no response to +CIMI, or +CFUN=1 returns an error result code, then there will be a problem with the SIM. Check to see if the SIM is a 3V SIM only, or support 1.8V. SARA-N2 series modules only support 1.8V compatible SIMs.

 Use the +NPIN AT command, to lock and unlock the SIM card.

12.3 Searching for network

When the module has started the network search process, poll the +NUESTATS AT command and view the Rx and Tx Time:

- If Rx Time is increasing then the module is trying to scan for a base station.
- If Tx Time is increasing then the module has found a base station and is trying to communicate with it.

If the Total Power and Signal Power values are different than -32767 (invalid) then the module has read the MIB and SIB signals from the base station.

Once an RRC connection is made, the +CSCON read command will return 1. Turn on the +CSCON URC which will be output at each RRC connection change.

12.4 Registering on the network

After a RRC connection is made to the base station the module will try and register with the network. If the module IMEI or IMSI is not allowed on the network, the module will disconnect from that base station and continue scanning for other base stations. This can be seen if the <mode> parameter of the +CSCON AT command shows the "1" and then "0" response without +CEREG changing to 1 or 5 means that the module was not able to register on that network.

In case the module is registered to the network, the <status> parameter of the +CEREG AT command will be 1 (registered) or 5 (registered & roaming).

After a short period, if no messages are being sent from the module, the +CSCON response will be "0" to show the RRC connection has been released by the eNodeB.

12.5 T3324 and T3412 timers

T3324 and T3412 timers are set by the network after the module registration. These timers control the amount of time the module will be in idle mode before entering Power Save Mode (T3324) and how long it will wait until automatically sending a Tracking Area Update message (TAU) (T3412)

The timers can be read out using the +CEREG command if the <mode> parameter is set to "4" or "5".

The timers are encoded by a bit pattern which is described in the 3GPP documentation. An example is available in Appendix A.

12.6 Power save mode

After the module has registered to the network and the RRC connection has been released, after T3324 timer has expired the module will enter the PSM. It is possible to query this state by polling the +NPSMR read command or configure the URC to automatically output this status when it changes.

If the <mode> parameter of +NPSMR AT command differs than 1 (PSM state) it means the module has not entered into PSM. This could mean either the T3324 timer is set to a very long period or that the network does not support the power save mode.

12.7 Ping

Issue the +NPING AT command to check if the module is able to send and receive data.

Check to see if the network can communicate to the internet, or it is needed another accessible server's IP address to ping.

To ping Google's DNS server:

```
AT+NPING="8.8.8.8"
```

To ping OpenDNS DNS server:

```
AT+NPING="208.67.222.222"
```

The information text response to the +NPING AT command will be issued after a few seconds. If the information text response is +NPINGERR: 1, the ping has timed out.

 The first ping might fail because it can take a few seconds to connect to the base station. Use the +CSCON URC to show when the module is connected.

12.8 Echo server

For a more advanced check on sending data to an external server, send data to the u-blox echo server at echo.u-blox.com.

 Because there is no DNS lookup function in the SARA-N2 module series, use the IP address server which is 195.34.89.241.

Command	Response	Description
AT+NSOCR="DGRAM",17,10000	0 OK	Create a UDP socket.
AT+NSOST=0,"195.34.89.241",7,5,"0102030405"	0,5 OK	Send data on socket 0.
	+NSONMI: 0,5	Receive data on socket 0.
AT+NSORF=0,5	+NSORF: 0,"195.34.89.241",7,5,"0102030405",0 OK	Request data from socket 0. Echo'd data received

13 Simple AT command example

Below is an example of AT commands and their responses in a scenario starting with the module turning on and registering to a network. It also shows pinging Google DNS and sending data to the u-blox echo server (The "OK" final result codes are removed from list to reduce clutter in the table).

Command	Response	Description
	u-blox	Welcome note
AT+CGMR		Get revision
ATI9		Get detailed revision
AT+CGSN=1		Get IMEI
AT+NCONFIG?		Check +NCONFIG for options
AT+NCONFIG="AUTOCONNECT", "FALSE"		Turn off the Auto Connect feature
AT+NRB	Restarting...	Reboot the module to take effect
	u-blox	Welcome note
AT+CSCON=1	OK	Turn on Base Station Connection State URC
AT+CEREG=1	OK	Turn on network registration state URC
AT+NPSMR=1	OK	Turn on PSM state URC
AT+CFUN=1	OK	Turn on module radio/modem
	+CEREG: 0	Not registering
AT+CIMI		Read IMSI from SIM
AT+COPS=1,2,"00101"	OK	Start manual registration to 00101 PLMN
	+CEREG: 2	Starting registration process, scan for Base stations
	+CSCON: 1	Found base station, RRC connection created
	+CEREG: 1	Registered to network
	+CSCON: 0	RRC released, now inside T3324 period
	+NPSMR: 1	Entered the Power Save Mode
AT+NPING="8.8.8.8"		Ping Google DNS
	+CSCON: 1	RRC connection to base station created
	+NPING: "8.8.8.8",45,1234	Ping result
	+CSCON: 0	RRC released, now inside T3324 period
AT+NSOCR="DRGAM",17,10000		Create UDP socket
	0	Socket "0" created
AT+NSOSTF=0,"195.34.89.241",7,0x000,3,"ABFB55"		Send 3 bytes to u-blox echo server on socket "0"
	0,3	Queued 3 bytes to be sent
	+NSONMI:0,3	Received 3 bytes on socket "0"
AT+NSORF:0,3		Request 3 bytes from socket "0"
	+NSORF: 0,"195.34.89.241",7,3,"ABFB55",0	Response
	+CSCON: 0	RRC released, now inside T3324 period

14 Debugging

There are a few ways to debug the module's connection and messaging problems. One way is to use the +NUESTATS command and URCs to view the module status.

14.1 Manual debugging with +NUESTATS

The +NUESTATS AT command displays the current status of the module's radio and cell information. It can also display the BLER and throughput measurements. By using historical analysis it is possible to compare the current statistics with previous statistics.

The +NUESTATS AT command only shows the last values seen by the radio in the module. Tx and Rx timers are accumulated since the radio was turned on.

14.1.1 +NUESTATS="RADIO"

It displays the radio statistics for signal power levels, Tx and Rx times, RSRP and RSQP.

When the module first tries to register with the network, the Tx time will be zero as it will not have instantly found a base station. The Rx time will increase to show it is scanning for a base station. Once a base station is found it is possible to see that it is attempting to transmit to the base station as the Tx time will start to increase. If the base station does not respond to the module's Tx, then the +CSCON: 1 URC will not be issued.

Once the module has an RRC connection, then the ECL, RSRP, RSRQ values allow to understand the RF link budget between the module and base station.

The Cell ID in this response is the physical network cell ID.

14.1.2 +NUESTATS="CELL"

It displays the cell information after the module has registered with the network.

Use this to confirm to check the correctness of the EARFCN or the Cell ID. The cell ID in this response is the eNodeB cell ID. This also provides RSRP, RSRQ, SNR and RSSI values much like the RADIO option provides.

14.1.3 +NUESTATS="BLER"

It displays the BLER and total number of bytes transmitted and received by the RLC Layer and Physical Layer.

Using this statistic it is possible to see if the module is having difficulty in communicating with the base station. Even if the module is in good coverage, ECL 0, there still might be issues causing the messages not to be sent or received. Check the Ack/Nak ratio to see a general view of the link quality.

14.1.4 +NUESTATS="THP"

It displays the throughput measurement for the RLC and physical layers.

These values provide an indication of the efficiency of the radio link. With bad BLER, these values will be low. With very good BLER, these values will be near the theoretical throughput of NB-IoT – and because of this, may not change over time, as it does not take into account the time to wake up, scan for base station, etc. This is simply over the protocol stack itself.

14.2 Manual debugging with URCs

By turning on the URCs for RRC connection, network registration and Power Save Mode status the module will provide information about the wake up, connection to the base station and the network registration.

Consider to issue `AT+CSCON=1`, `AT+CEREG=1` and `AT+NPSMR=1` commands especially when first powering on the module.

When the module starts the communication to the base station these URCs should be issued:

- `+CSCON: 1` Base station RRC Connection
- `+CEREG: 1` Registered to the network (or 5)
- `+NPSMR: 1` Module in Power Save Mode

See the section 12 about examples of how the statuses change when connecting and registering to the network.

14.3 Debug log stream

The module has a second UART interface which outputs the chipset log stream. This is always enabled and does not depend on the AT commands.

The log stream is in a binary format at a baud rate of 921600 bit/s. This is quite fast for a low powered MCU, but this can be recorded by a Cortex-M3 running at 96 MHz, like the NXP LPC 1768 – as it is available in the C027 application board.

14.3.1.1 Raw recording of log stream

Because the debug log stream is in a binary format, it can be quite difficult to understand the correctness of the recording. It is possible to verify this by looking at the recorded file in a text editor and seeing if there are any “%DBG:” tags in the binary garbage characters.

For example viewed in Notepad++:

```

15  FFNULNUL%DBG: >NULNULNULDC3gAACKaSTNULNULFFNULNULNUL@ST
16  STEOTNULNULNULNULNUL%DBG: ?NULNULNULogAACKaSUBSTXEOT NULSTXNUL` SUBSUBSUBCANNUL
17  DC1EOTNULNULNULNULNUL%DBG: ANULNULNUL-yAACKaSUBETXEOTFFNULIETXNUL` SUBSUBSUBEOTN
18  ESCNULNUL%DBG: UNULNULNULb%AACKaFF%NULDNUL%NUL@FF
19  FF<NULSOHBELIENO SOHNULSOHISOHISOHISOHNULNULNULNULSOHISOHISOHISOHNULNULNULSOHNULN
20  NULSTXNULNULSTXSOHENOANULNULNULNUL%DBG: VNULNULNUL,AAACK; NULSTXNULIETBNULservice
21  NULSTXNULNULSTXSOHENOANULNULNULNUL%DBG: YNULNULNULi;AACKaFF6NULDNUL6NUL@FFFF
22  <NULNULÿÿÿÿpSOHNULÿÿÿNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULNULN
23  CANNULFFNULCANNUL@
    
```

14.3.2 UE Monitor

A dedicated debug log monitoring application called UEMonitor is available. This application can be used to record and view the live debug output from the module. A separate user guide on this application is available.

With UEMonitor is possible to view the cell searching, connection and message sending/receiving processes. Some filters allow to show certain parts of the 3GPP protocol.

This tool can either view the live debug stream from the module's debug UART (GPIO1) or from a saved binary file.

Capturing these logs for debug purposes is highly recommended.

The screenshot shows the UEMonitor v3.18.0.10 interface. The main window displays a list of debug messages with columns for Index, UE ticks, Time, Name, and Parameters. A filter is applied: "NAS messaging". The selected message (Index 2771) is detailed in the right-hand pane.

Index	UE ticks	Time	Name	Parameters
1134	4667236	00:39.516099	PROTO_RRC_STATE_IND	PROTO_RRC_NULL 0 0
1554	8480438	00:41.092546	APPLICATION_REPORT	"*UFOTAS: 0.1"
1741	9381286	00:41.993394	APPLICATION_REPORT	"*NPSMR=1"
1742	9381744	00:41.993852	APPLICATION_REPORT	"OK"
1783	9533782	00:42.145890	PROTO_RRC_STATE_IND	PROTO_RRC_CELL_SELECTION 0 0
1838	9803222	00:42.415330	PROTO_L1_FOUND_CELL_REP...	LL1_MEASUREMENT_SSS_RESYNC 37...
1919	10618865	00:43.230973	PROTO_L1_FOUND_CELL_REP...	LL1_MEASUREMENT_SIB1 37 -32 6250
1930	10622619	00:43.234727	PROTO_RRC_STATE_IND	PROTO_RRC_IDLE 37 6250
1998	11613342	00:44.225450	PROTO_RRC_STATE_IND	PROTO_RRC_IDLE 37 6250
2275	19536071	00:52.148179	NAS_DBG_NAS_MSG	L3_EMM_ATTACH_REQ_UL_PDU
2290	19538116	00:52.150224	PROTO_RRC_STATE_IND	PROTO_RRC_CONNECTING 37 6250
2637	20295043	00:52.907151	APPLICATION_REPORT	"*CSCON: 1"
2682	20293121	00:52.907151	PROTO_RRC_STATE_IND	PROTO_RRC_CONNECTED 37 6250
2770	20407592	00:53.019700	NAS_DBG_NAS_MSG	L3_EMM_ID_REQ_DL_PDU
2771	20407745	00:53.019853	NAS_DBG_NAS_MSG	L3_EMM_ID_RSP_UL_PDU
3014	20635070	00:53.247178	NAS_DBG_NAS_MSG	L3_EMM_AUTH_REQ_DL_PDU
3426	21019714	00:53.631822	NAS_DBG_NAS_MSG	L3_EMM_AUTH_RSP_UL_PDU
4520	23834869	00:56.446977	PROTO_RRC_STATE_IND	PROTO_RRC_RELEASING 37 6250
4543	23869140	00:56.481248	PROTO_RRC_STATE_IND	PROTO_RRC_CELL_SELECTION 0 0
4547	23872741	00:56.484849	APPLICATION_REPORT	"*CSCON: 0"
4602	24143737	00:56.755845	PROTO_L1_FOUND_CELL_REP...	LL1_MEASUREMENT_SSS_RESYNC 37...
4681	24699279	00:57.311387	PROTO_L1_FOUND_CELL_REP...	LL1_MEASUREMENT_SIB1 37 -15 6250
4692	24703033	00:57.315141	PROTO_RRC_STATE_IND	PROTO_RRC_IDLE 37 6250
4760	25693786	00:58.305894	PROTO_RRC_STATE_IND	PROTO_RRC_IDLE 37 6250
5039	33872802	01:06.484910	NAS_DBG_NAS_MSG	L3_EMM_ATTACH_REQ_UL_PDU
5054	33874847	01:06.486955	PROTO_RRC_STATE_IND	PROTO_RRC_CONNECTING 37 6250
5710	36830413	01:09.442521	PROTO_RRC_STATE_IND	PROTO_RRC_CELL_SELECTION 0 0
5765	37104187	01:09.716295	PROTO_L1_FOUND_CELL_REP...	LL1_MEASUREMENT_SSS_RESYNC 37...
5845	37499725	01:10.111833	PROTO_L1_FOUND_CELL_REP...	LL1_MEASUREMENT_SIB1 37 -12 6250

The detailed view of the selected message (Index 2771) shows the following structure:

- Transport**
 - direction: UL_PDU
 - msg_type: L3_EMM_ID_RSP
 - len: 11
 - data: 7
 - Additional Info: 07-56-08-09-10-10-10-32-54-76-98
- NASMessage:** 0756080910101032547698
 - emmmMessage:
 - plain:
 - protocolDiscriminator = 0x7
 - securityHeaderType = 0x0
 - messageType = 0x56
 - body:
 - identityResponse:
 - mobileIdentity:
 - imsiTIMEIMESV:
 - oddEvenIndicator = 0x1
 - typeOfIdentity = 0x1
 - identityDigits = 0xeb300cc115

15 Power profile

3GPP NB-IoT has been developed for low power applications which provide more than 10 years of operation. It is useful to view the power profile of the module when developing the application to understand the various profiles in each coverage class, and what this means for the battery.

15.1 200 bytes, ECL1, without Release Assistance

Figure 3 shows a typical power profile of the SARA-N2 series modules sending 200 bytes in coverage class 1, with the Release Assistance feature disabled (AT+NSOSTF with 0x000 flag, or AT+NSOST)

- 1: Module wakes up and scans for a base station
- 2: Starts the RACH process and immediately gets an allocation
- 3: Sends 200 bytes
- 4: The module waits for the RRC release by the eNodeB after its 20 s of inactivity

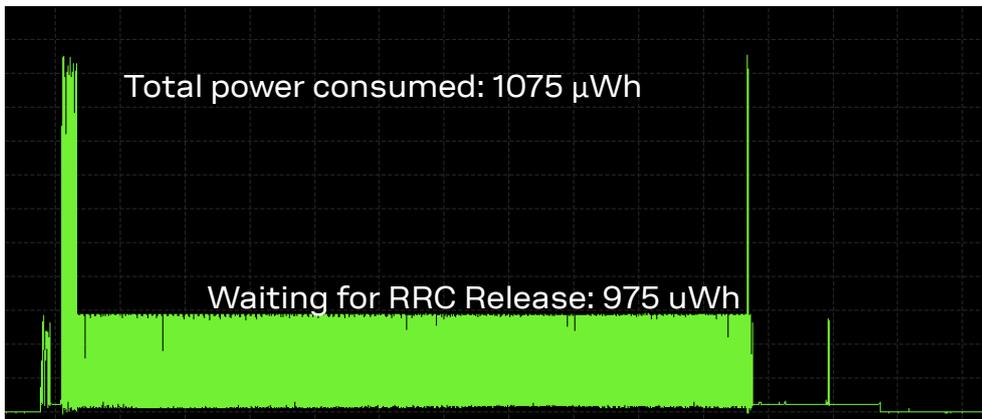


Figure 3: 200 bytes, ECL1, without the Release Assistance feature

15.2 200 bytes, ECL1, with Release Assistance

Figure 4 shows a typical power profile of the module sending 200 bytes in coverage class 1, with the Release Assistance feature enabled (AT+NSOSTF 0x200 flag).

- 1: The module wakes up and scans for a base station
- 2: Starts the RACH process and immediately gets an allocation
- 3: Sends 200 bytes
- 4: eNodeB releases RRC immediately

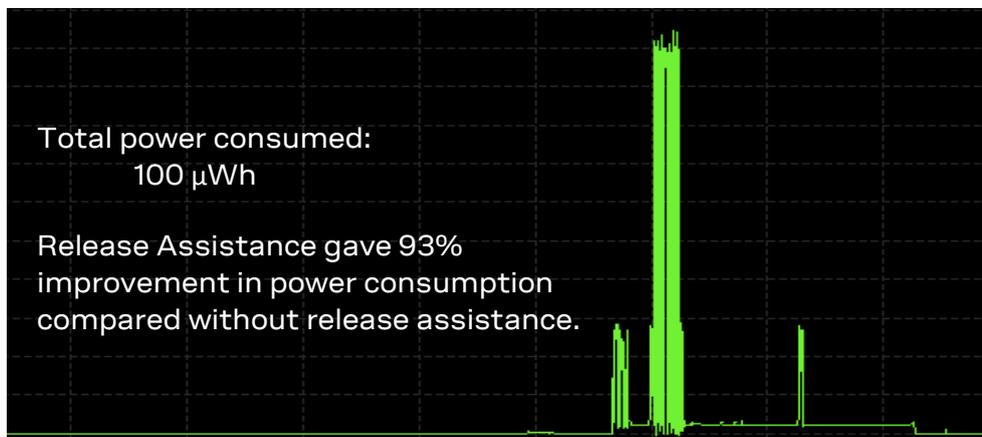


Figure 4: 200 bytes, ECL1, with the Release Assistance feature

15.3 Uplink allocations based on SNR

The UE is entirely under the control of the eNB and the network configuration. The UE must follow the network settings which are broadcast inside the System Information Blocks (SIB) and the allocations for the uplink and downlink data.

The SIB describes the method of attachment and what repetitions the UE must use to first transmit to the base station. Once a RRC connection is made, the base station then uses the perceived SNR to configure the uplink allocations the UE will use to transmit the messages.

Because allocations for each uplink/downlink are dynamically set by the base station it is difficult to calculate the power consumption of a single message deployed in the field.

15.3.1 Good SNR, coverage Class 2

Figure 5 shows an example profile of sending 200 bytes in Coverage Class 2 with “good” SNR. The first 5 transmit bursts are the random access procedure, which is specified by the SIB parameters. The next transmission bursts are from the UE sending the 200 byte message, according to the allocations provided by the base station.



Figure 5: Good SNR, coverage Class 2

From the debug log it was shown that the Transport Block Size (TBS) allocated was 43 bytes for each uplink chunk, with a repetition of just one. This allowed the UE to transmit the 200 byte message in just over 1 second, consuming 200uWh.

15.3.2 Bad SNR, coverage Class 2

Figure 6 shows an example profile of sending 200 bytes in Coverage Class 2 with “bad” SNR:



Figure 6: Bad SNR, coverage Class 2

From the debug log it was shown that the Transport Block Size (TBS) allocated was 32 bytes for each uplink chunk, with a repetition of 8 and 4. This time the UE transmitted the 200 byte message in 5.5 seconds, consuming 1.07 mWh – five times that as before.

16 Design for reduced power consumption

There are multiple factors which will contribute to the overall power consumption of the device. Some of them are listed in the next sections.

16.1 Hardware design

PCB layout, antenna matching and location will have an effect to the overall interference received by the module.

The antenna matching will have an effect on the current drawn when in Tx mode. Ideally the module should consume 230 mA for +23 dBm. Antenna positioning in the product will also have a role in the overall RF performance.

Interference to the module will increase the number of repetitions the module is configured to use and therefore increase the Tx and Rx time.

16.2 Release Assistance

The application developers should consider the use of the Release Assistance feature. This drastically reduces the power consumed by the module when sending data.

Applications could consider sending a special “service” type message to the cloud server which does not use the Release Assistance feature, letting the cloud service know that the UE will be still “online” for any downlink message that are required.

16.3 PSM and eDRX

Depending on the network configuration and permissions by the Mobile Network Operator, the PSM and eDRX timers should be configured for the application.

Applications which only send a message once a day and do not expect to have any downlink messages could configure eDRX to be off and enter directly the PSM.

Applications which require an acknowledgment back to the device could consider still using the Release Assistance feature but configure a long T3324 timer and eDRX – as the UE will still be able to be contacted within T3324 period before it goes into PSM.

16.4 Minimizing coverage Level 2

Network operators should provide enough coverage to allow devices to be mostly in coverage class 0 or 1. Depending on the NB-IoT deployment, the network could have large areas, or devices located in deep locations which unfortunately mean they operate in Coverage Class 2.

Coverage Class 2 uses high repetitions for the RACH process and also higher coding schemes when transmitting data and therefore fundamentally consumes more power than it would in the other coverage classes.

17 Network architecture mapping on AT commands

Both UDP socket commands and datagram commands use the IP data transport through the SGi.

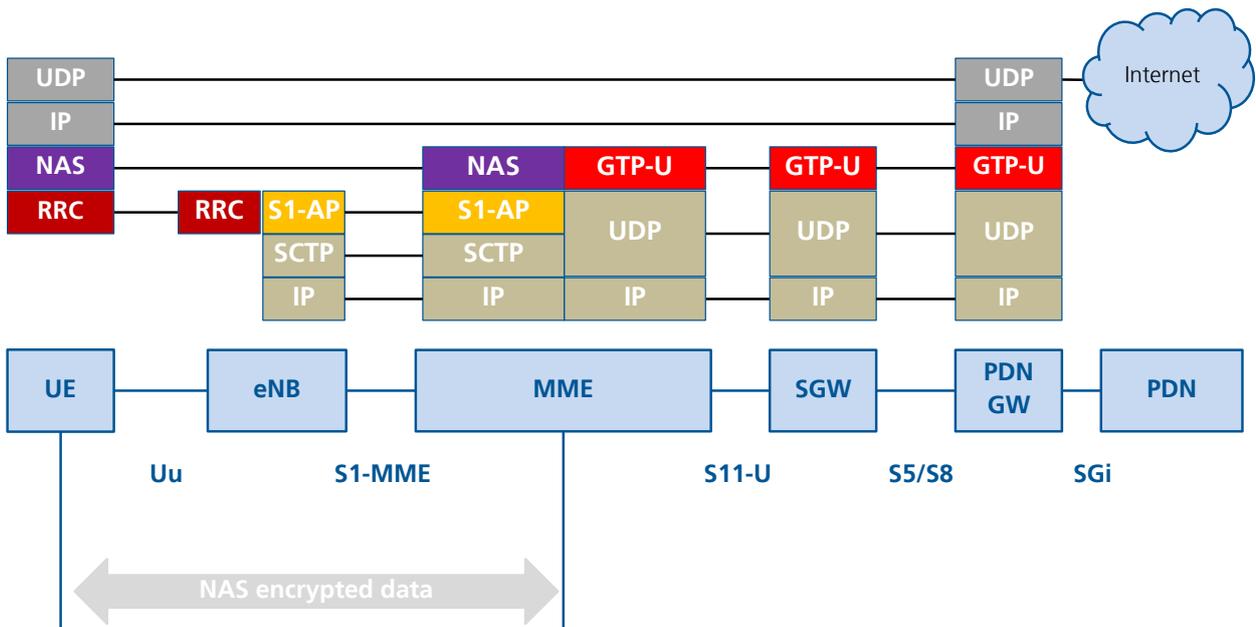
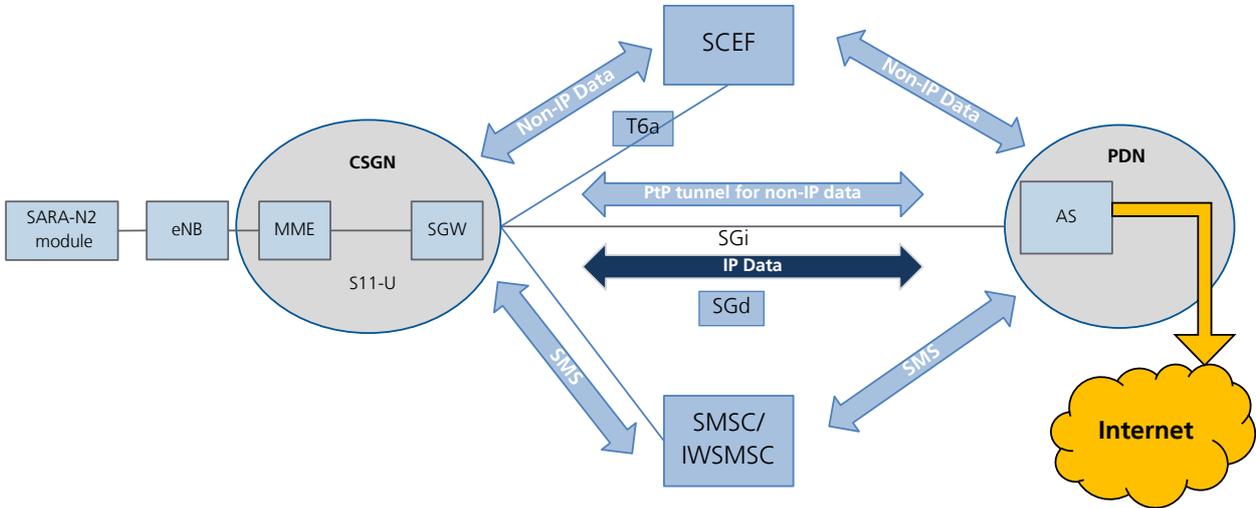


Figure 7: NB-IoT network architecture

18 NB-IoT best practices

18.1 Radio and network status polling

The application can monitor the radio and network status. A registration or an IP address for UDP/CoAP messages is mandatory in order to successfully send or receive data.



Use the follow AT commands to query the status:

- **AT+NPSMR**: to query the Power Save mode.
- **AT+CEREG**: to query the registration status to the network.
- **AT+CGPADDR**: to query if the module has an IP address.
- **AT+CSCON**: to query the connection status to the base station. This is only useful to see if Tx or Rx activity is happening. It should not be used to decide whether or not to send data.

18.2 Deep-sleep mode

SARA-N2 series modules are designed to enter a power save mode which allows batteries to last longer. After the module connects to a base station to send a message, the module will stay connected to a base station for a period of time after the last communication with the base station. The device will then go back into deep-sleep mode.

An application that sends lots of messages throughout the day will obviously keep the module awake and connected to a base station, consuming power.

In an ideal design the application should not require the device to send more messages than necessary. The cloud application should not need to send the module many messages either, although in a trial system the customer may want more activity to see the operation of the system. In these cases high capacity batteries or continuous power supply should be used.

18.3 Message size

The module has a limited dynamic message queue size. For IoT applications, the message size should be of the order of tens of bytes. UDP socket commands limit their payload size to 512 bytes. There is no indication when the UDP data has been sent.

Downlink data from the cloud server must also be 512 bytes or less, because otherwise the messages will be lost.

18.4 Message buffer

The module has an internal message buffer. If the module is unable to send the messages to the network before this buffer is full, because the application is queueing quicker than it can send them, then the UE will return ERROR for the +NSOST/+NSOSTF commands.

If a message cannot be sent because of communication issues between the module and eNB, the module will attempt to send the message a second time. If this fails, the message will be dropped. As +NSOST/+NSOSTF messages are UDP, there is no indication the message has been dropped.

18.5 Application architecture

Many developers coming from a GPRS type background may expect an always on type connection, normally using TCP. NB-IoT is not session oriented, latencies are much higher and the device will enter a power save mode. This is very different to always-on modems with “chatty” protocols like TCP.

UDP sockets do not create connections to servers; UDP is a connection-less datagram protocol. Because of this MO messages may not be received by the server and lost. The application should take this in to consideration and provide its own acknowledgements between the UE and server. CoAP is one protocol which can be used on top of UDP to provide this.

For resolving the issue of sending MT messages to a very sleepy module, when a MO message is sent to the cloud server, the cloud server will know the module is active and connected to the network. As seen in section 7 the connection is alive until the RRC connection is released by the network and then still contactable when paging inside the T3324 period. If there are MT messages to be sent to the module, the cloud server should send this message in this time.

19 FOTA

SARA-N2 series modules implement a FOTA solution based on CoAP. It is possible to configure the module's poll timer for when the module checks the FOTA CoAP server for new firmware. When the feature is enabled and a new package is available, the module will automatically download the FOTA update and provide URCs about its progress. The module's firmware is not updated automatically when the download has completed and so the application must start the upgrade process step.

19.1 Server

SARA-N2 series modules use a simple CoAP based server for their FOTA solution. This server must be installed by the customer on their own servers.

 A simple Node.js example of a FOTA CoAP server is available from u-blox. Appendix B describes the procedure on how to install this example.

19.2 Configuration

There are three steps for configuring FOTA:

- Select a FOTA component
- Configure the FOTA server IP address
- Set the FOTA poll timer.

To set the IP address issue the `AT+UCOAPS=0,<ip_addr>` command. The port value is optional and the default value is 5683.

To set the Poll timer issue the `AT+UFOTAPT=<period>` command. By default the period value is immediate and can be set to every hour, every 24 hours (1 day), every 168 hours (7 days) or every 720 hours (30 days).

To select the FOTA component issue the `AT+USELCP=2` command.

19.3 Status

When the FOTA process is running the module will output a +UFOTAS URC if the status changes. The URC will describe the FOTA state, containing two values, one value for the number of blocks remaining to be downloaded and the second value for the status.

The status can be any of 6 values:

- 0: No update available (Poll timer is running)
- 1: Poll timer has expired. The module can query the FOTA server
- 2: Writing the package to the module. A reboot will occur afterwards.
- 3: Pending transfer. The application must tell the module to resume FOTA
- 4: Module validating the package.
- 5: Module installing the package.

 Only when the status changes a URC will be issued. The query can be queried by means of the +UFOTAS read command.

19.4 Package download query

To query if there is a FOTA package available to download, use `AT+UFOTAPT=0`. To start the download and upgrade process, use `AT+UCOAPFWT=0`.

19.5 Example

Below is a typical example of the FOTA process.

In this example the application requests the FOTA process to start immediately using the AT+UFOTAPT=0 command.

Command	Response	Description
	+UFOTAS: 0,0	URC at module start up. The poll timer is running.
AT+USELCP=2	OK	Select the FOTA component.
AT+UFOTAPT=0	OK	This command should be executed if the FOTA is in 0 state.
	+UFOTAS: 0,1	URC to update that POLL timer is expired
ATI9	06.57,A07.03_ENG OK	Know the current FW version.
AT+UCOAPS=0,"ip_addr_FOTA"		Set the FOTA server IP address.
AT+CEREG?	+CEREG: 0,1	Verify the module registration
AT+USELCP=2	OK	Select FOTA component
AT+UFOTAS		Execution command will send a query message to server
	+UFOTAS: x,3	FOTA jumped to PENDING_TRANSFER state and number blocks to get for the update is x.
AT+UCOAPFWT=0	OK	File transfer is triggered. User can give actual no of blocks also.
	+UFOTAS: x,2	
AT+UFOTAS?	+UFOTAS: XXX,2	User can check the current status of file transfer by issuing +UFOTAS read command. XXX: show the actual no block left to transfer at the moment read command is issued
	+UFOTAS: 0,4	File transfer is completed and module is validating the package
	+UFOTAS: 0,5	Validation is successful and update package is going to be triggered
		Module restart.
	+UFOTAS: 0,1	After the module start up FOTA is jumped to "POLL_TIMER_EXPIRED_STATE".
ATI9	06.57,A07.03_DBG OK	Verify the updated FW version.

20 End user test (+UTEST)

The +UTEST AT command allows the user to set the module in non-signaling (or test) mode, or returns to the signaling (or normal) mode. In test/non-signaling mode, the module switches off the protocol stack for performing single tests which could not be performed during the signaling mode.

20.1 Enabling / Disabling the end user test

Enter the non-signaling (or test) mode before to use the +UTEST AT commands.

Command	Response	Description
AT+UTEST=1	OK	Enable the end user test feature.
AT+UTEST=0	OK	Disable the end user test feature. To return to normal mode it is possible also to reset the module or power off/on.

20.2 Rx tests

The receiver test provides a power meter type measurement, measuring the antenna RF level estimation.

Two parameters must be provided: the channel to receive on with an offset of +10000, and the time interval of the measurement.

```
AT+UTEST=2,<channel+10000>,<ms_period>
```

Command	Response	Description
AT+UTEST=2,106150,1000	+UTEST: 106150,1000,-119.8,-116.3,-113.8 OK	Command to be issued to measure the power on channel 6150 for 1 s. In the information text response the 3 values represents the minimum, average and maximum antenna RF level, expressed in dBm.

20.3 Tx tests

The transmitter test provides a transmitted signal on a particular channel, at a set power level.

Three parameters must be provided: the channel to transmit on with an offset of +10000, the power level of the signal and the period the transmitter is on for.

```
AT+UTEST=3, <channel+10000>,<power_dbm>,<ms_period>
```

Command	Response	Description
AT+UTEST=3,106150,15,20	+UTEST: 106150,15,20 OK	Command to be issued to transmit on channel 6150 for 20 ms @ 15 dBm.

21 Datagram messages with Huawei OceanConnect IoT platform

Huawei OceanConnect server allows datagram messaging to easily be sent and received. Dedicated AT commands have been implemented to interact with this IoT platform. The Huawei OceanConnect server is not always available. Consult the network operator if this platform has been installed.

 The Release Assistance feature is not available with the Huawei OceanConnect IoT platform.

For both sending and receiving datagrams, the AT command format is similar:

<length>, <data>

where <length> is the number of hex bytes that follows and <data> is the hex bytes. For example:

Command	Response	Description
AT+NMGS=10,0102030405060708090A	OK	This command would send a datagram containing the binary values 1 to 10 to the network as a single datagram. A datagram should not be longer than 1024 hexadecimal bytes.

 Datagrams sent and received by these commands are wrapped internally in a Constrained Application Protocol (CoAP) message and sent over UDP sockets to the IoT Platform. Although these commands use CoAP, these can only work with the Huawei OceanConnect IoT platform, not any other CoAP based IoT Platform.

21.1 Sending MO datagrams

Command	Response	Description
AT+NMGS=<number>, <data>	+NMGS:OK OK	The information text response indicates that the module has accepted the datagram. If AT+NSMI=1 has been set, then the URC +NSMI: SENT will be issued when the datagram has been acknowledge by the base station.

 Once the module accepted a datagram it cannot be removed and will be transmitted to the network as soon as radio conditions permit. The only way to clear the module's transmit queue is to reboot it. In good radio conditions, the transmission might take a few seconds. In bad radio conditions a transmission opportunity may not occur for minutes, days or weeks but the datagram will be transmitted once radio conditions are good enough.

When a MO message is queued, the module will try to send the message to the base station. It will only send the next message once the previous message has been sent. If there is a radio link failure (RLF), the device will re-scan the channel ranges and try to reconnect to a base station. There may be a back off time where the device goes into deep-sleep mode before trying again.

21.2 Querying MO datagram sent status

Command	Response	Description
AT+NQMGS	PENDING=1, SENT=4, ERROR=0 OK	The information text response indicates how many datagrams have been queued, sent and not sent.

Unlike the +NSMI: SENT indication, which shows when the datagram has been sent to the base station, there is no indication if the core network or CDP server has received the message. The customer will need to implement an application based reply if the notification is required to be given back to the device; however this is not best practice for IoT type products.

21.3 Receiving MT datagrams

 Verify with Huawei about the use of the OceanConnect server on how to send MT datagrams from the cloud application.

To output any received MT datagram use the +NMGR AT command.

Command	Response	Description
AT+NMGR	<length>, <data> OK	The information text response contains a downlink datagram that has been received by the module. The datagram is now removed from the module's queue. A datagram will not be longer than 512 bytes.
AT+NMGR	OK	This indicates that no downlink datagrams are present in the module's queue.

One +NMGR response containing one datagram is issued for each AT+NMGR. To check for multiple downlink datagrams, multiple AT+MGR commands must be issued. There is no indication to the OceanConnect server if the module received the datagram.

If the +NNMI URC has been enabled, the module will send a URC on the UART interface after receiving a MT datagram. If the module's application, on customer device, is not prepared to read the message as it is presented on the UART interface, the message will be lost.

Command	Response	Description
	+NNMI:<number>, <data>	The information text response contains a downlink datagram that has been received by the module. The datagram is removed from the module's queue.

21.4 Querying MT datagram received status

Command	Response	Description
AT+NQMGR	BUFFERED=0, RECEIVED=0, DROP PED=0 OK	The information text response indicates how many datagrams have been received, queued and not received.

21.5 Avoiding data loss

While the NB-IoT system is built to avoid data loss due to RF signal issues, buffers are of a finite length and hence it is necessary to design with the limitations in mind.

In the uplink direction, it is recommended that the application on the device enables the send message indications +NSMI URC and only puts another datagram into the module when the

previous datagram has been confirmed as sent. This has the added advantage that the send buffer can be managed by the application (so, for instance, stale data is not left queued in the module).

In the downlink direction, it is recommended that the customer server does not allow datagrams to build up on the IoT platform, i.e. the system design should be such that, for instance, transmission of the next downlink datagram would not occur until the previous downlink datagram had been sent on to the device. This is because, should a transfer be in progress when the radio link completely fails, the entire downlink buffer within the network will be cleared and any datagrams forwarded to the core network by the OceanConnect server could be lost.

If the cloud application requires notification of MT datagram delivery, the UE application must send back an acknowledgement message itself as there is no provision within NB-IoT or the IoT platform being used.

21.6 Send message indication +NSMI

Enables and disables indications when an upstream message is sent.

If indications are turned on, the +NSMI URC will be issued when the datagram has been successfully sent and acknowledged by the network.

Command	Response	Description
AT+NSMI=0	+NSMI: OK OK	Turns off +NSMI URC.
AT+NSMI=1	+NSMI: OK OK	After a datagram has been successfully sent and acknowledged by the network the module will issue the +NSMI: SENT URC.

The state of the send message indications may be queried as follows:

Command	Response	Description
AT+NSMI?	+NSMI=1 OK	The default value is 0, in which case no confirmation is given. The command setting is not stored in the module NVM hence, if the parameter was set to 1 and is later read as 0, this means the module has rebooted.

21.7 New message indications +NNMI

Notification of receipt of a datagram may be requested as follows:

Command	Response	Description
AT+NNMI=0	+NNMI: OK OK	Turns off the +NNMI URC indications.
AT+NNMI=1	+NNMI: OK OK	When a datagram has been received by the module, the +NNMI: <length>, <data> URC will be issued and the datagram will be deleted from the module's internal memory.
AT+NNMI=2	+NNMI: OK OK	When a datagram has been received by the module, the +NNMI URC will be issued but the datagram will be retained inside the module. The datagram may then be retrieved from the module using AT+MGR.

The state of the new message indications may be queried as follows:

Command	Response	Description
AT+NNMI?	+NNMI=1 OK	The default value is 0, in which case the module must be polled with AT+NMGR for received messages. This value is not stored in the module NVM hence, if the parameter was set to 1 or 2 and is later read as 0, this means the module has rebooted.

Appendix

A T3324 / T3412 timer values

A.1 T3412 timer (GPRS timer 3)

The purpose of the GPRS timer 3 information element is to specify GPRS specific timer values. The GPRS timer 3 is a type 4 information element with a 3 octet length. The GPRS timer 3 information elements are coded as described in 3GPP TS 24.008 [4], figure 10.5.147a and table 10.5.163a.

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

```

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

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

-  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 [5]). 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 [5]).

A.2 T3324 timer (GPRS timer 2)

The purpose of the GPRS timer 2 information element is to specify GPRS specific timer values, e.g. for the timer T3302 or timer T3319. The GPRS timer 2 is a type 4 information element with a 3 octet length. The GPRS timer 2 information elements are coded as shown in figure 10.5.147 and table 10.5.163 in 3GPP TS 24.008 [4].

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

```

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

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

B FOTA server installation example

An example of a FOTA COAP server is available from u-blox. It has been written in Node.js and is only provided as an example. A more complete FOTA service should be developed by the customer for a complete live deployment solution based on the FOTA description in section 19.

To install the example COAP server FOTA service, follow the following instructions:

- 1: Install Node.js from <https://nodejs.org/en/download/>
- 2: Create a folder called "FOTA_server"
 - a. Place the `coap_server_FOTA.js` file in the folder
 - b. Place the "pkg" subfolder in the folder
- 3: Open a command prompt in the FOTA server folder and check the node.js installation:
 - a. `node -v`
- 4: Install Node.js packages; type the following into the command prompt:
 - a. `npm init` (choose default values when requested)
 - b. `npm install coap -save`
 - c. `npm install delay -save`
 - d. `npm install fs -save`
 - e. `npm install events -save`
 - f. `npm install json -save`
 - g. `npm install lodash -save`
 - h. `npm install ip -save`
- 5: Run the server
 - a.

```
node coap_server_FOTA.js v l t n
serv_type:v
pack_type:l
resp_type:t
data_type:n
coap test server is up @ :10.38.20.179:5683
```

When new packages are available from u-blox, place them in the pkg folder as before.

C List of acronyms

Abbreviation	Definition
AMQP	Advanced Message Queue Protocol
AT	Attention
CDP	Connected Device Platform
DC	Data Channel
DCE	Data Communications Equipment
DL	Downlink
DTE	Data Terminal Equipment
EARFCN	Extended Absolute Radio-Frequency Channel Number
GPRS	General Packet Radio Service
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Station Identity
IP	Internet Protocol
MCS	Message Coding Scheme
MO	Mobile Originated
MT	Mobile Terminated
NB-IoT	Narrow Band Internet of Things
PCI	Physical Channel ID
SIM	Subscriber Identity Module
SMS	Short Message Service
SNR	Signal to Noise Ratio
TAU	Tracking Area Update
TE	Terminal Equipment
UE	User Equipment
UL	Uplink
URC	Unsolicited Result Code
UUID	Unique User Identification

Table 2: Explanation of the abbreviations and terms used

Related documents

- [1] u-blox SARA-N2 series Data Sheet, Docu No UBX-15025564
- [2] u-blox SARA-N2 AT Commands Manual, Docu No UBX-16014887
- [3] 3GPP TS 36.321 Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification
- [4] 3GPP TS 24.008 - Annex G (informative): 3GPP specific cause values for mobility management
- [5] 3GPP TS 24.301 - Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3
- [6] 3GPP TS 36.331 - Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); 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-Nov-2016	pwar	Initial release
R02	02-Feb-2017	pwar	Emphasis more on UDP. Include protocol states and IP transport diagrams
R03	23-Mar-2017	pwar	Update NUESTATS for new B655SP2 version. Removed Neul IoT Platform references.
R04	27-Oct-2017	pwar	Updated for U06.57 A03.02 ES firmware. (B657SP2 protocol stack from HiSilicon)
R05	20-Jul-2018	pwar	Added FOTA, UTEST and CoAP sections, minor corrections.

Contact

For complete contact information, visit us at www.u-blox.com.

u-blox Offices

North, Central and South America

u-blox America, Inc.

Phone: +1 703 483 3180
E-mail: info_us@u-blox.com

Regional Office West Coast:

Phone: +1 408 573 3640
E-mail: info_us@u-blox.com

Technical Support:

Phone: +1 703 483 3185
E-mail: support@u-blox.com

Headquarters

Europe, Middle East, Africa

u-blox AG

Phone: +41 44 722 74 44
E-mail: info@u-blox.com
Support: support@u-blox.com

Asia, Australia, Pacific

u-blox Singapore Pte. Ltd.

Phone: +65 6734 3811
E-mail: info_ap@u-blox.com
Support: support_ap@u-blox.com

Regional Office Australia:

Phone: +61 2 8448 2016
E-mail: info_au@u-blox.com
Support: support_ap@u-blox.com

Regional Office China (Beijing):

Phone: +86 10 68 133 545
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office China (Chongqing):

Phone: +86 23 6815 1588
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office China (Shanghai):

Phone: +86 21 6090 4832
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office China (Shenzhen):

Phone: +86 755 8627 1083
E-mail: info_cn@u-blox.com
Support: support_cn@u-blox.com

Regional Office India:

Phone: +91 80 405 092 00
E-mail: info_in@u-blox.com
Support: support_in@u-blox.com

Regional Office Japan (Osaka):

Phone: +81 6 6941 3660
E-mail: info_jp@u-blox.com
Support: support_jp@u-blox.com

Regional Office Japan (Tokyo):

Phone: +81 3 5775 3850
E-mail: info_jp@u-blox.com
Support: support_jp@u-blox.com

Regional Office Korea:

Phone: +82 2 542 0861
E-mail: info_kr@u-blox.com
Support: support_kr@u-blox.com

Regional Office Taiwan:

Phone: +886 2 2657 1090
E-mail: info_tw@u-blox.com
Support: support_tw@u-blox.com