LTE and NR UE Simulator

Version: 2025-12-12

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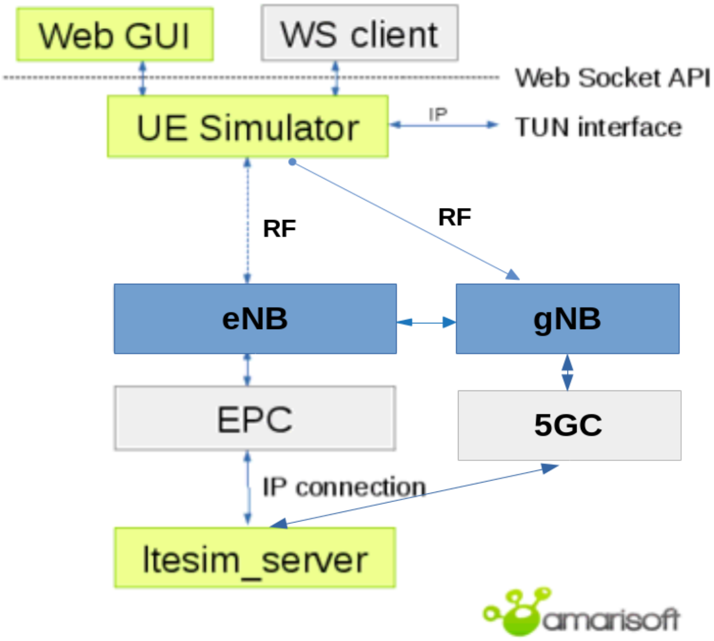
1 Introduction

LTEUE is a LTE and NR UE simulator.
It simulates one or more UEs (typically hundreds of UEs) by communicating through a RF system with eNodeB and core network.
It allows to test LTE and NR procedures and to simulate a large number of users on eNodeBs.
It supports NR both in Standalone (SA) and Non-standalone (NSA) mode.
It also supports connecting to a 5G core network through a ng-eNB.

The LTEUE is connected to network via eNB through the air on one side.
On the other side it can be managed using WebSocket and IP traffic may be reachable with a Linux TUN network interface.



2 Features

- Simulate a large number of UEs sharing the same spectrum.
- IP traffic simulator (ping, constant bitrate UDP, HTTP).
- Remote API based on Websocket and JSON.
- Command line monitor.
- Access to external programs such as iPerf in tunnel interface mode with IPv6 support and automatic DNS configuration.
- Includes PHY, MAC, RLC, PDCP, RRC and NAS layers.
- Support of all ciphering and integrity protection algorithms including ZUC.

2.1 4G LTE

- LTE Release 8 support with features up to Release 17.
- FDD/TDD support.
- Bandwidths: 1.4, 3, 5, 10, 15 and 20 MHz.
- MIMO DL support.
- 1024QAM support in DL, 256QAM in UL.
- MBMS support.
- Category M1 support for FDD, HD-FDD and TDD.
- NB-IoT support (category NB1/NB2) with multi-tone, multi-carrier and multi-DRB support.
- Release 17 NTN support in NB-IoT.
- Release 16 WUS support in NB-IoT and Cat-M1.
- eDRX and PSM support.
- Multi-UE fading channel simulator.
- ETWS and CMAS support.
- Semi-persistent scheduling (SPS) support.
- TTI bundling support.
- EPS user plane integrity support.

2.2 5G NR

- Release 18 EN-DC support for 5G NSA mode.
- Release 18 5G SA support.
- FDD/TDD support.
- Support of all FR1 carrier spacings for DL, UL and SSB.
- Bandwidth up to 50 MHz or 100MHz depending on the product version.
- Up to 8 DL MIMO layers.
- Up to 4 UL MIMO layers.
- 256QAM support in DL and UL, 1024QAM in DL.
- Support of DCI formats 0-0, 0-1, 1-0 and 1-1.
- Support of PUCCH formats 0, 1, 2, 3 and 4.
- Periodic and aperiodic CSI reports.
- Periodic and aperiodic SRS.

- Multi-BWP support.
- Carrier aggregation support (DL and UL CA).
- Supplementary Uplink support.
- ETWS and CMAS support.
- RRC Inactive mode support.
- eDRX, MICO and active time support.
- Multi-UE fading channel simulator.
- Release 17 NTN support.
- Release 18 RedCap and eRedCap support.

3 Requirements

3.1 Hardware requirements

- A fast PC:
  - For best performances, a quad core Intel Core i7 CPU (Haswell architecture or later) is recommended. Support of the AVX2 instruction set extension is required to run the software.
  - At least 1 Gigabit Ethernet ports.
  - At least 2 GB of RAM.
  - At least 1 GB of hard disk space.
  - The video adapter does not matter.
- Radio front end
  - Amarisoft PCIe SDR
  - Ettus Research USRP N2x0 (SBX daughterboard). For MIMO 2x2, a second N2x0 with the SBX daughterboard and a USRP MIMO cable are needed.
  - Ettus Research USRP B2x0.
  - Ettus Research USRP X3x0.
  - Lime Microsystem LimeSDR
- Appropriate antennas for the intended LTE frequencies or cables and attenuators to connect to a UE.
- An eNodeB connected to a LTE Core Network must be available to communicate.

3.2 Software requirements

- A 64 bit Linux distribution. Fedora 42 is the officially supported distribution.
  The following distributions are known as compatible:
  - Fedora 22 to 42
  - Cent OS 7
  - Ubuntu 14 to 24

  Your system requires at least GLIBC 2.17.

  Other distributions can be used provided the radio frontend drivers are available for them.

4 Installation

4.1 Linux setup

4.1.1 Packages

The Remote UE feature of LTEUE uses the SCTP protocol for which the necessary packages are not usually installed. In order to install them, do as root user:

- Fedora

  ```
  dnf install lksctp-tools kernel-modules-extra
  ```

- Ubuntu

  ```
  sudo apt-get install lksctp-tools linux-image-extra-3.13.0-24-generic
  ```

  Note that linux-image-extra package name may differ depending on your kernel version.

To verify that SCTP kernel module is running, do as root user:

```
checksctp
```

If it reports that the protocol is not supported,

- check if you have a /etc/modprobe.d/sctp-blacklist.conf file
- edit it to comment the 'blacklist sctp' line

Then reboot the PC in case the Linux kernel was upgraded too.

4.1.2 OpenSSL

LTEUE has been compiled against openssl version 3.5.4.
If your system does not have compatible version installed you may have this error message at startup:

```
error while loading shared libraries: libssl.so.3: cannot open shared object file: No s
```

To overcome this problem, you may:

- Copy libssl.so.3 and libcrypto.so.3 from `libs` subdirectory of your release tarball.
  If you have installed software with automatic install script, this should have been done automatically.
- Compile and install proper openssl version yourself

In case of persisting issue, raise a ticket from our support site at `https://support.amarisoft.com/` with the information provided by below commands executed in LTEUE directory:

```
uname -a
ls -l
ldd ./lteue
openssl version
```

4.2 Linux setup for best performance

LTEUE requires a lot of CPU power and it has hard real time requirements (a maximum latency of 3 ms is required).

In order to get the lowest latency, it is recommended to set up the `performance` frequency governor for each CPU core. An example is included in the `lte_init.sh` script given with LTEUE.

Some buggy drivers are known to block the CPU during a few tens of ms. When it happens, LTEUE displays `UHD status: L=X U=Y S=Z`. One known problem is the DRM KMS cable polling. The script `lte_init.sh` disables it automatically.

Other drivers such as Wifi controllers can give the same problem. In order to avoid such problems, remove all unnecessary peripherals from the PC.

4.3 RRH setup

Please refer to sub section of your radio frontend to set it up.
When configured, you will have to select it (See [RRH selection], page 6).

4.3.1 Amarisoft PCIe SDR

Read the PCIe SDR documentation (`trx_sdr.pdf`).

4.3.2 Ettus Research USRP

Read the UHD Compatible RF frontends documentation (`trx_uhd.pdf`).

4.3.3 Lime Microsystems LimeSDR

Use LimeSuiteNG software suite located at `https://github.com/myriadrf/LimeSuiteNG`, which contains Amarisoft plugin. During build it creates the needed trx_limesuite.so (build directory) file, which can be sim linked or copy pasted.

4.4 LTEUE installation

Decompress the LTEUE archive to a convenient place. The executable lteue can be launched from this directory.

4.4.1 RRH selection

To select appropriate RF frontend to use, please execute following command:

```
./config/rf_select.sh <type>
```

Where `type` is your frontend type:

- sdr
- n2x0
- b2x0
- n3x0
- x3x0
- limeMini
- limeSDR

NB: you can lanch following command to see available frontends:

```
./config/rf_select.sh
```

4.4.2 License key installation

LTEUE needs a license key file to run. *It is associated to your PC, so if you replace it or change its hardware configuration you must contact Amarisoft to get a new license key.*

The following steps are needed to get this license file:

- Run LTEUE:

  ```
  ./lteue config/ue.cfg
  ```

  It says that the license key is not present and prints a 16 digit hexadecimal code.
- Send by mail to `delivery@amarisoft.com` this hexadecimal code to your contact at Amarisoft. You will get back the `lteue.key` license key file.

- Copy the lteue.key file to the ${HOME}/.amarisoft/ directory (${HOME} is the home directory of the root user). You can use the shell variable AMARISOFT_PATH to change this path.

Once the license key is installed, lteue should start normally.

4.5 Initial testing

First update config/ue.cfg configuration file to match your eNB frequency and bandwidth by editing:

- dl_earfcn
- sample_rate

Look at ue_list section to match UE SIM parameters on MME side.

Check your eNB is running.

Start the LTEUE software as root user. root privileges are needed to use real time scheduling priority.

```
./lteue config/ue.cfg
```

You should see SIB found message displayed.

Type ue in the monitor, you should see list of UEs with their states.

If UE has been able to register to network, its EMM_STATE should be registered.

If not, look at logs on both UE and eNB/MME side.

4.6 5G SA initial testing

Update config/ue-nr-sa.cfg configuration file to match your gNB frequency, bandwidth and numerology by editing:

- dl_nr_arfcn
- ssb_nr_arfcn
- bandwidth
- subcarrier_spacing

Look at ue_list section to match UE SIM parameters on AMF side.

Check your gNB is running.

Start the LTEUE software as root user. root privileges are needed to use real time scheduling priority.

```
./lteue config/ue-nr-sa.cfg
```

You should see SIB found message displayed. If the gNB is not running, the message TRX discontinuity too wide might appear.
Type ue in the monitor, you should see list of UEs with their states.

4.7 Multiple UE case

To activate the simulation of multiple UEs, the parameter multi_ue should be set to true. In this mode, UE simulator may have difficulties to synchronize with eNB signal. If such a case occurs, you should see that UE is able to receive SIBs but further communications fails with bad CRC on physical layer.
This means that you should adjust the parameter global_timing_advance (See [global_timing_advance], page 30) in your configuration file. The global_timing_advance parameter can be set automatically by using the special value -1 (global_timing_advance:-1).

If automatic mode is set, the UE simulator uses the timing advance from the first received RAR for all UEs. This is the default behaviour.

You can also manually adjust the timing advance for all UEs in case you still experience CRC erros with automatic mode. You can check TA value on eNB side and set it to minus 1 in UE (global_timing_ advance = TA[enb] - 1). if you are using simulator with Amarisoft eNB/gNB, you can type `t` at eNB/gNB screen and look at PRACH traces.

Then, use `ta` value minus one as `global_timing_advance`.

```
PRACH: cell=01 seq=17 ta=2 snr=18.5 dB
PRACH: cell=01 seq=22 ta=2 snr=18.0 dB
PRACH: cell=01 seq=23 ta=2 snr=18.5 dB
PRACH: cell=01 seq=29 ta=3 snr=17.6 dB
```

In this example, adjust `global_timing_advance` to 1.

If you are using another eNB and you do not have access to eNB logs and information, you can enable the PHY and MAC layer logs in UE simulator and look for `ta` value in MAC traces

```
12:13:37.086 [MAC] -  0001 ta=13 ul_grant=128768 c_rnti=0x0047
```

In this example, you should set the `global_timing_advance` to 12.

If all the simulated UEs are expected to share the same timing advance and if this timing advance will likely need further adjustments (moving UEs, NGSO NTN scenario, ...) the parameter `apply_ta_commands` can be set to apply the TA commands received by the network. The `apply_ta_commands` parameter is supported only in NB-IoT and NR.

To summarize:

- `apply_ta_commands` set to true: the UE simulator can change the timing advance of ALL UEs upon reception of the RAR and TA commands during the runtime
- `global_timing_advance` set to -1: the UE simulator can change the timing advance of ALL UEs only ONCE, upon reception of the first RAR
- `global_timing_advance` set to a <value>: the UE simulator statically fixes the timing advance of ALL UEs at start-up and the it is never adjusted

4.8 Multiple UE case with Channel Simulator

In multi_ue mode, because all UEs share the same physical layer, the timing advance cannot be adjusted independently for each UE. However, this can be achieved by using the [Channel Simulator], page 50, with the parameter [delay_sim], page 54, set to true.

With `delay_sim`, a different timing advance for each UE can be simulated by applying a cycling shift on each UE uplink signal. It assumes that the all timing advances stay in a certain range, the center of this range is set either by the first received RAR or by the value of global_timing_advance.

When `delay_sim` is set to true, the `apply_ta_command` is not applicable.

4.9 Resources

When using a big amount of UE (> 32), you need to check in your eNB and MME configurations that enough resources are available.

4.9.1 Amarisoft eNB

If your are using Amarisoft eNB for your simulation, you may need to increase SRS resources so that your UE can simultaneously connect to eNB.

You can check you are running into this issue if you find such message in your eNB log file:

```
11:44:06.533 [RRC] -  01 005d RRC connection request: ue_allocate_resources() fail
```

Please take a look at `srs_dedicated` parameter in eNB documentation.

Here is an example to allow more than 1000 UE on eNB:

```
srs_dedicated: {
    srs_period: 320,
    srs_bandwidth: 3,
    srs_hopping_bandwidth: 0,
    cyclic_shift: 0,
},
```

Depending on the number of UEs simulated, you may also need to provision enough resources for SR (Scheduling Request) and CQI (Channel Quality Indicator) reporting. One way of checking if all your resources are available, is to take a look at the eNB log. In the header part, you always see the following information:

```
# SR resource count=480
# CQI resource count=960
# SRS resources: offsets=32 freqs=10 total=640
```

In this example, the eNB has SR resources to serve 480 UEs, CQI resources to serve 960 UEs and SRS resources for 640 UEs. You can increase the SR resources by increasing the value of `sr_period`. The CQI resources could as well be increased by reducing its periodicity `cqi_period`. Depending on the number of UEs that you would like to simulate, you may as well need to increase the following parameters in SIB2:

- `n1PUCCH-AN` to add more RB (Resource Blocks) for SR
- `preambleTransMax` to increase the number of retries after PRACH collision

4.9.2 Amarisoft MME

If your are using Amarisoft MME for your simulation, you may need to increase IP allocation range so that your UE can simultaneously connect to network.

You can check you are running into this issue if you find such message in your MME log file:

```
11:47:54.643 [NAS] -  0041 Can't allocate new IPv4 address
```

Please take a look at `first_ip_addr`, `last_ip_addr` and `ip_addr_shift` parameter in eNB documentation.

Here is an example to allow more than 1000 UE on MME:

```
first_ip_addr: "192.168.4.2",
last_ip_addr: "192.168.7.254",
ip_addr_shift: 0,
```

Please make sure to change the `net_mask` in `mme-ifup` script as well to go with your IP allocation range.

5 Using web interface

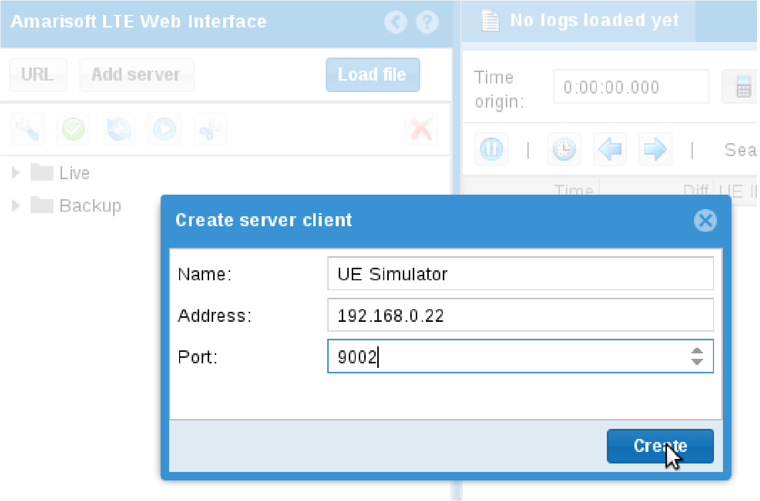
You can configure your UEs and test scripts using configuration file or you can dynamically use remote API. As an example, the Amarisoft Web interface will allow you to make basic tests.

5.1 Configuration

First enable remote API by setting `com_addr` in configuration file.

If you want to add UEs, you also need to enable `multi_ue`.

Then, on Web interface, click on `Add server` button and set UE `com_addr`



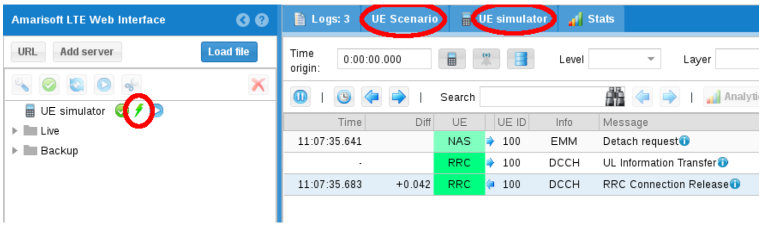
Create server client

Name: UE Simulator

Address: 192.168.0.22

Port: 9002

When Web interface is connected, you should see a green lightning icon on left panel, logs displayed on center panel and a two new tabs on top:
`UE Scenario` will be used to define scenarii.
`UE Simulator` is to control your UE simulator instance.



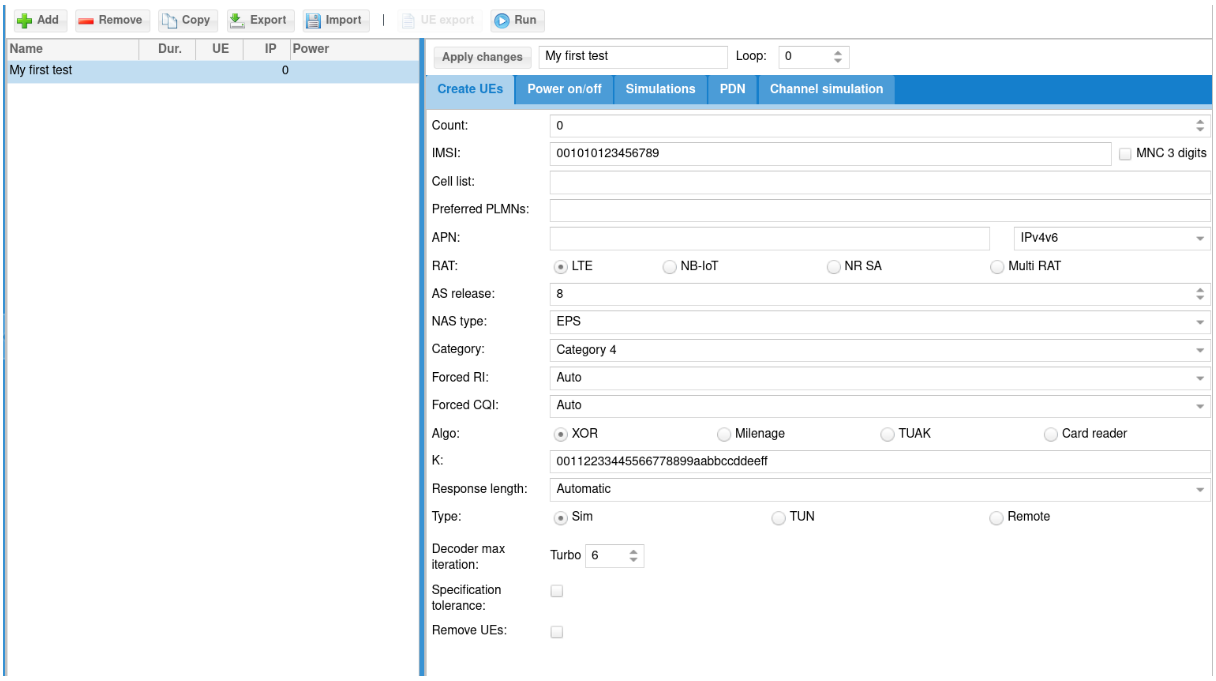
Time	Diff	UE	UE ID	Info	Message
11:07:35.641		NAS	100	EMM	Detach request
-		RRC	100	DCCH	UL Information Transfer
11:07:35.683	+0.042	RRC	100	DCCH	RRC Connection Release

5.2 Scenario tab

5.2.1 Create scenario

Click on the `UE Scenario` tab.
Click on `Add` button and select `New scenario`.

The scenario panel will be displayed on right.
After modification, click on `Apply changes` to commit them.



Name	Dur.	UE	IP	Power
My first test			0	

My first test — Loop: 0

Count: 0
IMSI: 001010123456789 □ MNC 3 digits
Cell list:
Preferred PLMNs:
APN: IPv4v6
RAT: ● LTE ○ NB-IoT ○ NR SA ○ Multi RAT
AS release: 8
NAS type: EPS
Category: Category 4
Forced RI: Auto
Forced CQI: Auto
Algo: ● XOR ○ Milenage ○ TUAK ○ Card reader
K: 00112233445566778899aabbccddeeff
Response length: Automatic
Type: ● Sim ○ TUN ○ Remote
Decoder max iteration: Turbo 6
Specification tolerance: □
Remove UEs: □

5.2.2 Create UEs tab

You will then define for the UE that will be created their configuration:

`Count` Number of UE to create.
If set to 0, the scenario shall only be applied to an already created UE.

`IMSI` IMSI of each UE.
To differentiate each UE, the special character $ or `${f(i)}` can be added.
$ will be replaced by the UE index and `${f(i)}` will be replaced by the result of the mathematical formula `f(i)` where `i` is the UE index. Ex: `${i+64}`
NB: if IMSI are all the same, your MME must support it (For Amarisoft MME, check that `multi_sim` parameter is true).

`RAT` RAN technology of the UE: either LTE, NB-IoT, LTE + NR (5G NSA) or NR (5G SA).

`category` UE category. This field is not present in NR SA.

`Forced RI` Forces RI return by UE to base station. If set to 0, UE will estimate it.
We recommend to force it to 2 when UE category is > 2.

`Forced CQI`
Forces CQI return by UE to base station. If set to 0, UE will estimate it.
We recommend to force it to when UE category is > 2.

`K` USIM secret. As for IMSI, $ or `${f(i)}` can be used.

`OP` USIM OP. Only available for milenage. As for IMSI, $ or `${f(i)}` can be used. Configure either OP or OPc.

`OPc` USIM OPc. Only available for milenage. As for IMSI, $ or `${f(i)}` can be used. Configure either OP or OPc.

`Algo` USIM Algo. Can be XOR or milenage.

`Type` Allow to select simulation mode between default simulation, tunnel interface mode and remote UE mode.

`Setup script`
Used with tunnel interface mode and remote UE mode as `tun_setup_script` parameter

`Remote address`
Used with remote UE mode as `rue_addr`.

5.2.3 Power on/off tab

If `Power on/off` is checked, simulation will generate on and off period for each UE and place inside each on period defined simulations.
Scenario will try to put as many simulation as possible, depending on parameters.

`Duration` Duration of the simulation in seconds.
All simulations and power off/on commands will be over before this duration.
If can be seen as the maximum simulation duration.

`Connection attempts/s`
Number of maximum UE connection attempt per second.

`Max simultaneous connected UE`
Maximum number of simultaneously connected UE.
Simulation will avoid any power on until this limit is reached, in other words, next power on will occur after new power off.

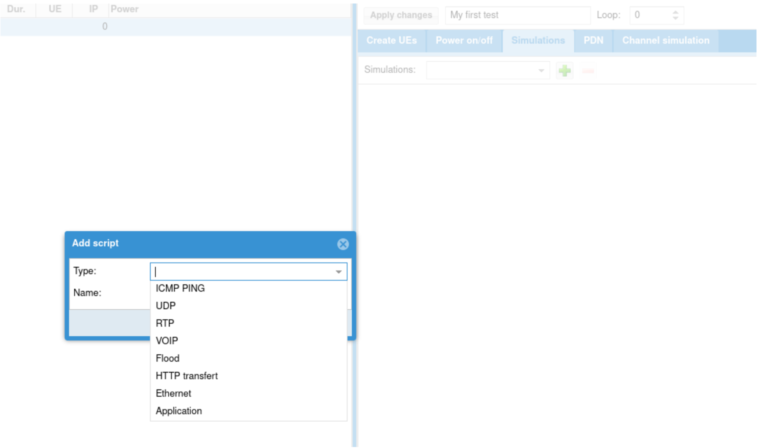
`Power on duration`
Duration in seconds of power on period. UE will remain powered on during this time and them will power off, allowing a new UE to connect.

`Power off duration`
Minimum duration in seconds of power off period. When powered off, a UE will remain powered off at least this time before being candidate to power on again.

5.2.4 Simulations tab

The simulation allow you to create different type of IP traffic simulation.
You can add several simulation per scenario.
Each simulation will be placed inside each power on period of each UE.

Click on add button and select simulation type:



My first test

Loop: 0

The following parameters apply to all simulations:

`Start delay`
Script start delay in seconds.
If power off/on procedure is not activated, script starts after this delay. If power on/off procedure is activated, you should always set a delay as power on procedure may take a while unless it is what you want to do.

`Duration` Duration of the script in seconds.

5.2.4.1 Internal IP simulations

You can choose the following simulations:

`ICMP Ping` Perform ICMP Ping request.

`UDP` Send UDP constant bitrate traffic.

`RTP` Send RTP constant bitrate traffic.

`VOIP` Simulate voice RTP traffic using statistical model.

`Flood` Send UDP packet burst

`HTTP transfert`
Send HTTP requests.

`Application`
Launches an external application.
Note that TUN mode must be enabled on UE.

For more detail on configuration, See [IP simulation messages], page 86.

5.2.4.2 External application

You can replace predefined simulation by a custom application.
For this, choose `Application` in IP simulation list. See [ext_app], page 76, for its configuration.

When started, the external application will fork a process and return its standard output and error.

To handle dedicated application, please take a look at `libsim_custom.js` file in `LTEWWW` component.
You can add specific result handler using `tag` for association.

Note that it requires associated UE to be configured in tunnel mode or with remote UE mode and thus IP simulations can’t be mixed.

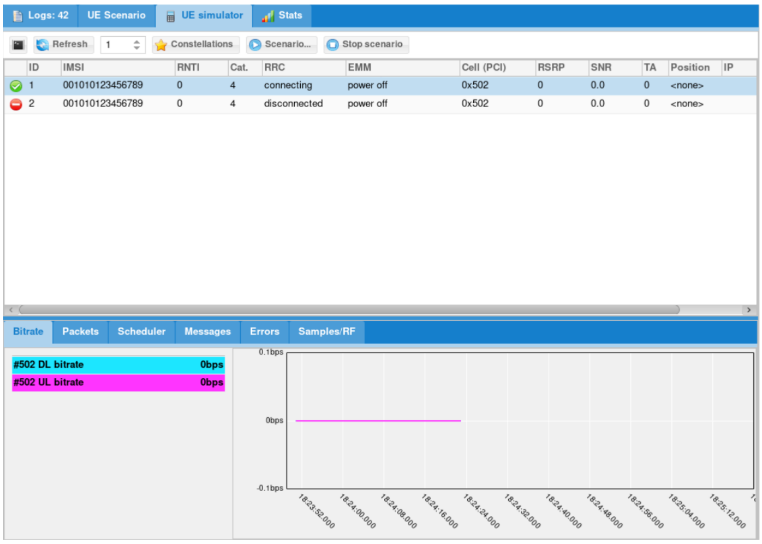
5.2.5 Export scenario

The `Export` will generate json config file that you can directly integrate in your UE configuration file.
Thus, you can start several time same scenario directly from command line.

5.3 UE tab

When selecting UE tab, several area are displayed.

- One to perform actions
- One for UE list that allows you to perform action and it
- One with various real time charts providing informations



	ID	IMSI	RNTI	Cat.	RRC	EMM	Cell (PCI)	RSRP	SNR	TA	Position	IP
✓	1	001010123456789	0	4	connecting	power off	0x502	0	0.0	0	<none>	
⊖	2	001010123456789	0	4	disconnected	power off	0x502	0	0.0	0	<none>	

#502 DL bitrate	0bps
#502 UL bitrate	0bps

5.3.1 Actions

`Refresh` button will force refresh of UE list. Else it is done regularly and refresh period is defined by the number field on the right.

`Start` button will allow you to start predefined scenario.
Note that only scenario that create UEs will be proposed.

`Stop` button will stop any pending simulation on UE simulator.

5.3.2 UE list

The UE list displays list of UE and their state.
You can click on the first icon to power on and off UE.
Right click on any UE to perform more actions:

- Power on/off
- Connect pdn: enter APN for PDN to connect
- Scenario: apply scenario on this UE (Only scenario without UE creation can be used).

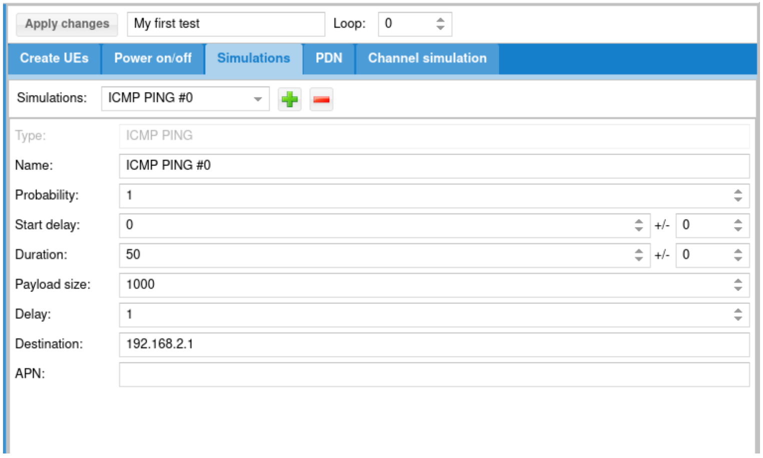
5.3.3 Statistics

Here you can find some general real time statistics.

5.4 Scenario example

- First create a scenario in `UE scenario` tab and call it `My first test`.

- Select `Simulations` tab and add ICMP ping:



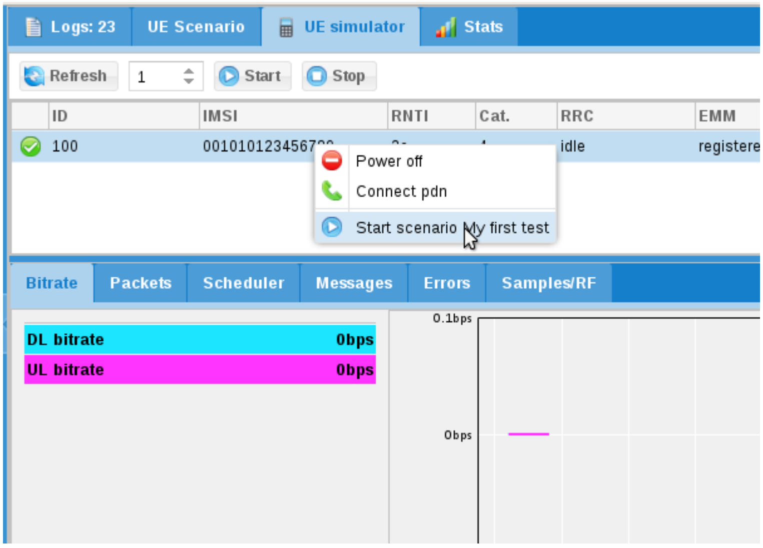
My first test

Loop: 0

Simulations: ICMP PING #0

Type:	ICMP PING		
Name:	ICMP PING #0		
Probability:	1		
Start delay:	0	+/-	0
Duration:	50	+/-	0
Payload size:	1000		
Delay:	1		
Destination:	192.168.2.1		
APN:			

- Click on `Apply changes`
- Go to `UE Simulator tab`.
- Click on red icon to power on UE and right click on UE:

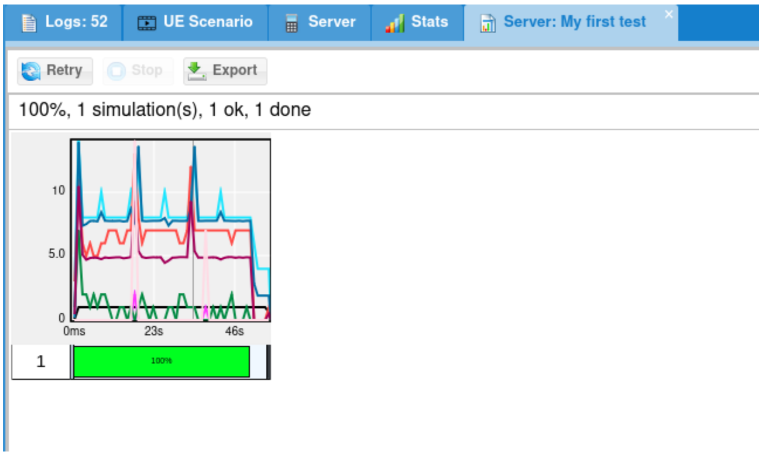


	ID	IMSI	RNTI	Cat.	RRC	EMM
✓	100	0010101234567			idle	registere

DL bitrate 0bps
UL bitrate 0bps

- Select `My first test`. A new tab is created to follow scenario.
- Select scenario tab

5.5 Executing scenario tab



100%, 1 simulation(s), 1 ok, 1 done

Following buttons are available:

- Reset will flush logs
- Retry will start scenario again
- Stop will stop current scenario
- Export will export in a CSV file scenario results

5.6 Example

Let's try the following exercise:

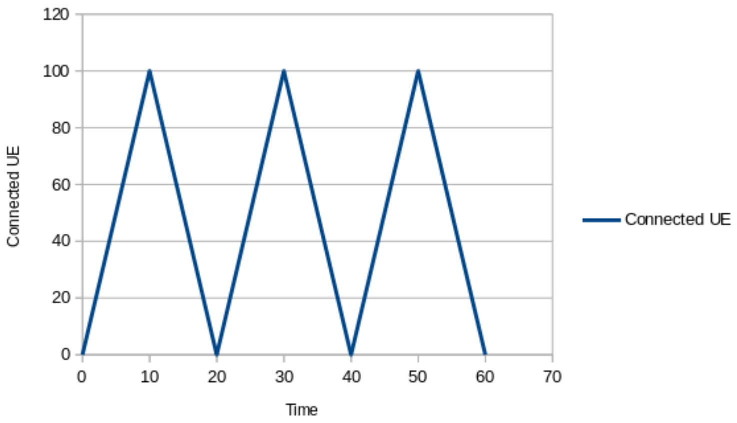
- 100 UE have to be connected simultaneously.
- 20 UE will connect every second.

- Each UE will stay connected 10s
- Each UE can't be powered of less than 10s
- Scenario will last 1 minute.
- UE will perform HTTP transfer and pings.

Let's create a new scenario.
First, we need to estimate the amount of necessary UE.
If we set only 100 UE:

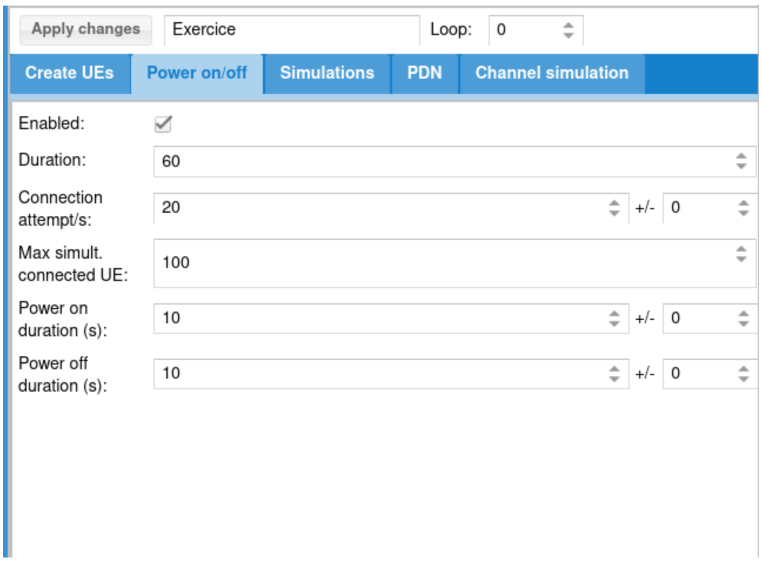
- The first one will connect at t=0s and disconnect at t=10s
- The last one will connect at t=5s (100 UE will take 5s to connect at 20 caps).
- From t=10s, UE will start to disconnect but there will be no non connected remaining UE to connect again as UE have to stay disconnected at least 10s.

This implies between t=10s and t=20s, total amount of connected UE will decrease to 0 at t=20s. As a result:



So what can we do ?
We can reduce power off duration but this will imply all UE will stay disconnected 0s !
And we can increase the amount of UE to have a constant pool of disconnected UE.

Let's do this:



Exercice

Loop: 0

Enabled: ✓

Duration: 60

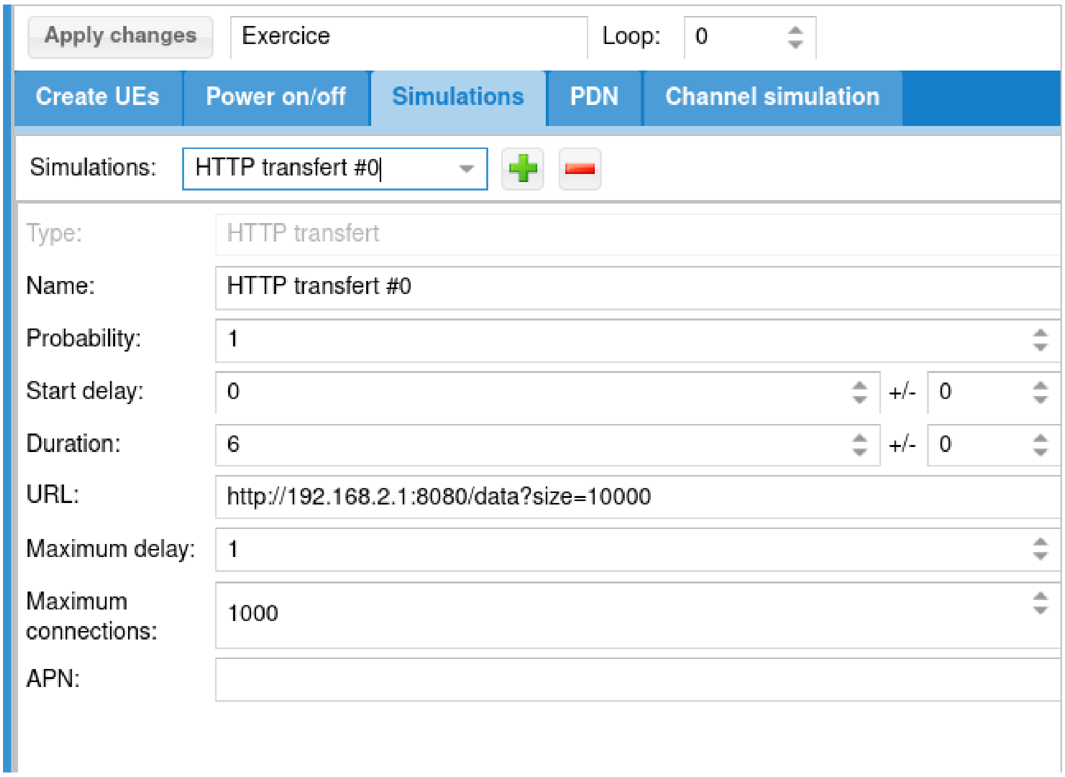
Connection attempt/s: 20 +/- 0

Max simult. connected UE: 100

Power on duration (s): 10 +/- 0

Power off duration (s): 10 +/- 0

Then we can add our scripts:



	Exercice
Loop:	0
Simulations:	HTTP transfert #0
Type:	HTTP transfert
Name:	HTTP transfert #0
Probability:	1
Start delay:	0 +/- 0
Duration:	6 +/- 0
URL:	http://192.168.2.1:8080/data?size=10000
Maximum delay:	1
Maximum connections:	1000
APN:	

With this configuration, HTTP transfer will last 6s.
As power on duration is 10s, it means HTTP transfer will start 2s after power on and will stop 2s before power off.

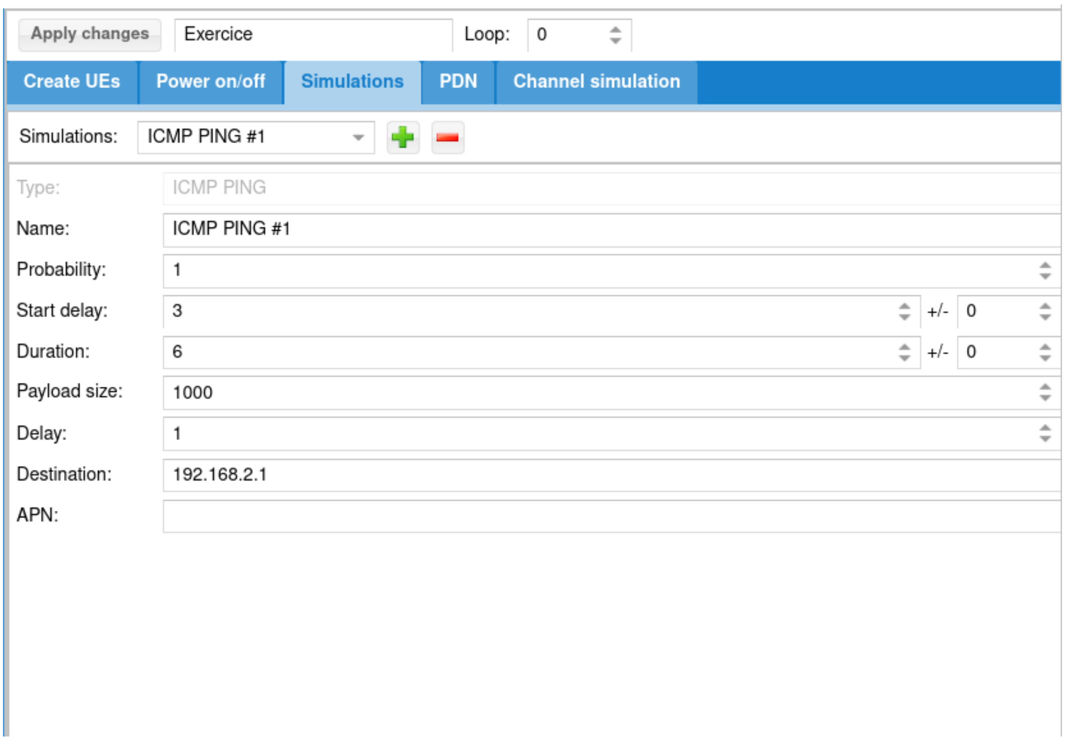
Take a look at URL: `http://192.1.168.4.1:8080/data?size=10000`

This URL will be interpreted by `ltesim_server` embedded HTTP server as a transfer of 10000 byte(s).

Note that `ltesim_server` must be started with HTTP server enabled:

```
sudo ./ltesim_server -a 192.168.4.1 -H 8080
```

Then add ping



Exercice

Loop: 0

Simulations: ICMP PING #1

Type: ICMP PING

Name: ICMP PING #1

Probability: 1

Start delay: 3 +/- 0

Duration: 6 +/- 0

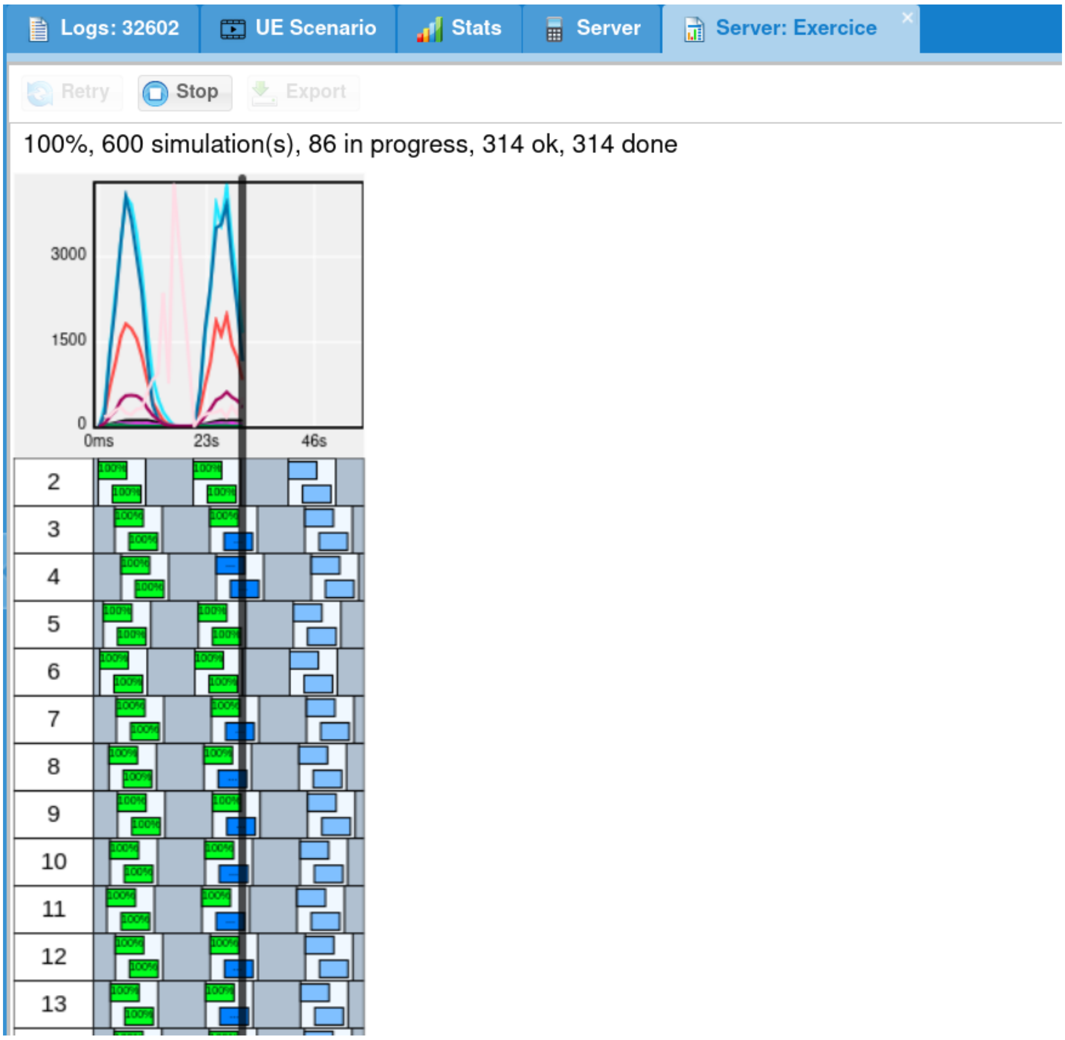
Payload size: 1000

Delay: 1

Destination: 192.168.2.1

APN:

And start it



100%, 600 simulation(s), 86 in progress, 314 ok, 314 done

6 Configuration reference

6.1 Configuration file syntax

The main configuration file uses a syntax very similar to the Javascript Object Notation (JSON) with few extensions.

1. Supported types:
   - Numbers (64 bit floating point). Notation: `13.4`
   - Complex numbers. Notation: `1.2+3*I`
   - Strings. Notation: `"string"`
   - Booleans. Notation: `true` or `false`.
   - Objects. Notation: `{ field1: *value1*, field2: *value2*, .... }`
   - Arrays. Notation: `[ *value1*, *value2*, .... ]`
2. The basic operations `+`, `-`, `*` and `/` are supported with numbers and complex numbers. `+` also concatenates strings. The operators `!`, `||`, `&&`, `==`, `!=`, `<`, `<=`, `>=`, `>` are supported too.
3. The numbers `0` and `1` are accepted as synonyms for the boolean values `false` and `true`.
4. {} at top level are optional.
5. `"` for property names are optional, unless the name starts with a number.
6. Properties can be duplicated.
   If properties are duplicated, they will be merged following [JSON merge rules], page 21, with overriding occuring in reading direction (last overrides previous).
   Ex:

   ```
   {
       value: "foo",
       value: "bar",
       sub: {
           value: "foo"
       },
       sub: {
           value: "bar"
       }
   }
   ```

   Will be equivalent to:

   ```
   {
       value: "bar",
       sub: {
           value: "bar"
       }
   }
   ```

7. Files can be included using *include* keyword (must not be quoted) followed by a string (without :) representing the file to include (path is relative to current file) and terminating by a comma.
   Arrays can't be included.
   Merge will be done as for duplicate properties.
   If *file1.cfg* is:

   ```
       value: "foo",
       include "file2.cfg",
       foo: "foo"
   ```

And *file2.cfg* is:

```
    value: "bar",
    foo: "bar"
```

Final config will be:

```
{
    value: "bar",
    foo: "foo"
}
```

8. A C like preprocessor is supported. The following preprocessor commands are available:

   `#define` *`var expr`*
   : Define a new variable with value *expr*. *expr* must be a valid JSON expression. Note that unlike the standard C preprocessor, *expr* is evaluated by the preprocessor.

   `#undef` *`var`*
   : Undefine the variable *var*.

   `#include` *`expr`*
   : Include the file whose filename is the evaluation of the string expression *expr*.

   `#if` *`expr`*
   : Consider the following text if *expr* is true.

   `#else`
   : Alternative of `#if` block.

   `#elif`
   : Composition of `#else` and `#if`.

   `#endif`
   : End of `#if` block.

   `#ifdef` *`var`*
   : Shortcut for `#if defined(var)`

   `#ifndef` *`var`*
   : Shortcut for `#if !defined(var)`

   In the JSON source, every occurrence of a defined preprocessor variable is replaced by its value.

9. Backquote strings: JSON expression can be inserted in backquote delimited strings with the `${expr}` syntax. Example: `‘abc${1+2}d‘` is evaluated as the string `"abc3d"`. Preprocessor variables can be used inside the expression. Backquote strings may span several lines.

6.1.1 JSON merge rules

Merge overriding direction depends on context, i.e source may override destination or the opposite.
JSON merge is recursive for Objects and Arrays.

Example, merging

```
{
    foo: { value: "bar" },
    same: "one",
    one: 1
}
```

with

```
{
    foo: { value: "none", second: true },
    same: "two",
    two: 1
}
```

Will become:

```
{
    foo: { value: "bar", second: true },
    same: "one",
    one: 1
    two: 1
}
```

assuming first object overrides second one.

In case of Array merging, the final array length will be the maximum length of all merged arrays.
For each element of the final array, merge will be done considering defined elements only.
Ex:

```
{
    array: [0, 1, 2, { foo: "bar" } ],
    array: [3, 4],
    array: [5, 6, 7, { bar: "foo" }, 8 ]
}
```

Will be merged to:

```
{
    array: [5, 6, 7, { foo: "bar", bar: "foo" }, 8 ],
}
```

6.2 Global properties

`log_filename`

String. Set the log filename. If no leading `/`, it is relative to the configuration file path. See [Log file format], page 95.

`log_options`

String. Set the logging options as a comma separated list of assignments.

- *layer*.level=*verbosity*. For each layer, the log verbosity can be set to `none`, `error`, `info` or `debug`. In debug level, the content of the transmitted data is logged.
- *layer*.max_size=*n*. When dumping data content, at most `n` bytes are shown in hexa. For ASN.1, NAS or Diameter content, show the full content of the message if `n > 0`.
- *layer*.payload=[0|1]. Dump ASN.1, NAS, SGsAP or Diameter payload in hexadecimal.
- *layer*.key=[0|1]. Dump security keys (NAS and RRC layers).
- *layer*.crypto=[0|1]. Dump plain and ciphered data (NAS and PCDP layers).
- phy.signal=[0|1]. Dump binary received signal data of the physical layer to another file (*log_filename*.bin). The currently available data are QAM constellations and channel estimation for PDSCH, PUSCH and SRS. The GUI can be used to display them. Note: the size of the binary signal data is larger than the textual logs, so they should be enabled only when needed.

- phy.rep=[0|1]. Log the NPUSCH/NPDSCH allocations and repetitions in each subframe (NB-IoT UE only).
- phy.dci_size=[0|1]. Log the expected DCI sizes (NR UE only).
- phy.csi=[0|1]. Log the computed CSI information.
- phy.cell_meas=[0|1]. Log some cell related statistics.
- phy.cch=[0|1]. Log number of CCH symbols and SINR.
- phy.ntn=[0|1]. Log timing updates performed for NTN.
- rrc.cell_meas=[0|1]. Log RRC cell measurements.
- nas.plmn=[0|1]. Log the PLMNs used by the NAS PLMN selection.
- time=[sec|short|full]. Display the time as seconds, time only or full date and time (default = time only).
- time.us=[0|1]. Dump time with microseconds precision.
- file=cut. Close current file log and open a new one.
- file.rotate=now. Move and rename to the same directory or to the directory pointed by `file.path` and open a new log file (Headers are kept).
- file.rotate=*size*. Every time log file size reaches *size* bytes, move and rename to the same directory or to the directory pointed by `file.path`, and open a new log file (Headers are kept).
  Size is an integer and can be followed by K, M or G.
- file.rotate=#*count*. Everytime number of logs in log file reaches *count*, move and rename to the same directory or to the directory pointed by `file.path`, and open a new log file (Headers are kept).
  Size is an integer and can be followed by K, M or G.
- file.path=*path*. When log rotation is enabled (`file.rotate` set), rename and move current log to this path instead of initial log path.
- append=[0|1]. (default=0). If 0, truncate the log file when opening it. Otherwise, append to it.

Available layers are: `phy`, `mac`, `rlc`, `pdcp`, `rrc`, `nas`, `ip`, `ikev2`, `swu`, `nwu`, `ipsec`

`log_sync`
Optional boolean (default = false). If true, logs will be synchronously dumped to file.
Warning, this may lead to performances decrease.

`rf_driver`
Object. Parameters of the radio driver. See [Radio driver configuration], page 27.

`tx_gain`
Float or array of floats. Transmit gain in dB. The range is device dependent. For the PCIe SDR board, the range is between 0 and 89.75 dB. For the USRP N2x0 device with the SBX daughterboard, the range is 0 to 31.5 dB. With an array of floats a different gain is specified for each channel.

`rx_gain`
Float or array of floats. Receive gain in dB. The range is device dependent. For the PCIe SDR board, the range is between -11 and 77 dB (the exact limits depend on the RX frequency). For the USRP N2x0 device with the SBX daughterboard, the range is 0 to 31.5 dB. With an array of floats a different gain is specified for each channel.

`udc_ports`
Optional array of objects. Each object contains the configuration of the corresponding UDC port.

Each object contains the following properties:

`args`
String. Set the UDC configuration parameters. Each parameter composing the string is separed by semicolon (See [args configuration], page 95).

`cmd`
String. Specifies the path to the script for the UDC configuration (See [UDC configuration reference], page 94). The script is called once for each configured `udc_port` with the following command line arguments:

- `args`: (See [args], page 24)
- `lo_freq`: (See [lo_freq], page 24)
- `min_freq`: automatically set by the software, spectrum minimum frequency for aggregated cells using the same `udc_port`
- `max_freq`: automatically set by the software, spectrum maximum frequency for aggregated cells using the same `udc_port`
- `freq`: automatically set by the software, FR2 cell central frequency, for each `rf_port` using the same `udc_port`
- `bandwidth`: automatically set by the software, FR2 cell bandwidth, for each `rf_port` using the same `udc_port`

`lo_freq`
Optional float. Specifies the UDC LO frequency in MHz to be configured. If not present, it will be automatically computed.

`tx_power_offset`
Optional float. Measured in dB, negative value. It corresponds to the amount of attenuation between the SDR and the UDC IF port.
The default value is 0, in case of aggregated cells with combiner the attenuation is computed as -10*log10(COMBINER_PORTS).

`cell_groups`
Array of object. Parameters for each group of similar cells. See [Cell group configuration], page 27.

`ue_list`
Array of object. Each element gives the configuration of a UE. See [UE configuration], page 34.

`custom_freq_band`
Optional object or array of objects. Define a non standard LTE or NR frequency band. Standard bands can also be overriden by this option. If the uplink information is not provided, it is assumed to be the same as the downlink (TDD band). Use an array of objects if you want to define more than one custom band.

For LTE bands, the following parameters are available:

`band`
Range: 1 to 256.

`dl_earfcn_min`
Range: 0 to 262143.

`dl_earfcn_max`
Range: 0 to 262143.

`dl_freq_min`
Float. Low DL frequency in MHz.

`ul_earfcn_min`
Optional integer. Range: 0 to 262143.

`ul_earfcn_max`
Optional integer. Range: 0 to 262143.

`ul_freq_min`
Optional Float. Low UL frequency in MHz.

`ntn` Optional boolean. True if this is a NTN band.

For NR bands, the following parameters are available:

`band_nr` Range: 1 to 1024. NR band number.

`dl_freq_min`
Float. Range: 0 to 65535. Minimum DL frequency in MHz. Use 0 if no DL.

`dl_freq_max`
Float. Range: 0 to 65535. Maximum DL frequency in MHz. Use 0 if no DL.

`ul_freq_min`
Float. Range: 0 to 65535. Minimum UL frequency in MHz. Use 0 if no UL. If not provided, use the same value as DL (TDD).

`ul_freq_max`
Float. Range: 0 to 65535. Maximum UL frequency in MHz. Use 0 if no UL.

`ssb_scs` Array of integers. List of allowed SSB subcarrier spacing for this band. Allowed values: 15, 30, 120 or 240.

`f_raster` Enumeration: 100, 15, 15_30, 15_30_100, 60_120, 100_enhanced. Frequency raster in kHz.

`ssb_case_c`
Boolean. True if SSB case C is enabled on this band.

`min_40mhz_bw`
Boolean. True if the minimum allowed bandwidth on this band is at least 40 MHz. This information is used to select the CoReSet #0 table in standalone mode.

`delta_gscn`
Optional enumeration: 1, 3, 7, 16 (default = 1). GSCN step size.

`ntn` Optional boolean. True if this is a NTN band.

`rue_bind_addr`
Optional string. Set it to enable and define *lterue* bind address.

`user_thread_count`
Optional integer (default = 1). Sets number of threads for external application launcher and tun_setup_script.

`com_addr` Optional string. Address of the WebSocket server remote API. See [Remote API], page 59.
If set, the WebSocket server for remote API will be enabled and bound to this address.
Default port is 9002.
Setting IP address to [::] will make remote API reachable through all network interfaces.

`com_name` Optional string. Sets server name. UE by default

`com_ssl_certificate`
: Optional string. If set, forces SSL for WebSockets. Defines CA certificate filename.

`com_ssl_key`
: Optional string. Mandatory if *com_ssl_certificate* is set. Defines CA private key filename.

`com_ssl_peer_verify`
: Optional boolean (default is false). If *true*, server will check client certificate.

`com_ssl_ca`
: Optional string. Set CA certificate. In case of peer verification with self signed certificate, you should use the client certificate.

`com_log_lock`
: Optional boolean (default is false). If *true*, logs configuration can't be changed via `config_set` remote API.

`com_log_us`
: Optional boolean (default is false). If *true*, logs sent by `log_get` remote API response will have a `timestamp_us` parameters instead of `timestamp`

`com_auth` Optional object. If set, remote API access will require authentication.
Authentication mechanism is describe in [Remote API Startup], page 61, section.

`passfile` Optional string. Defines filename where password is stored (plaintext).
If not set, `password` must be set

`password` Optional string. Defines password.
If not set, `passfile` must be set.

`unsecure` Optional boolean (default false). If set, allow password to be sent plaintext.
NB: you should set it to true if you access it from a Web Browser (Ex: Amarisoft GUI) without SSL (https) as your Web Browser may prevent secure access to work.

`com_log_count`
: Optional number (Default = 8192). Defines number of logs to keep in memory before dropping them.
Must be between 4096 and 2097152).

`license_server`
: Configuration of the Amarisoft license server to use.
Object with following properties:

`server_addr`
: String. IP address of the license server.

`name` Optional string. Text to be displayed inside server monitor or remote API.

`tag` Optional string. If set, server will only allow license with same tag.

Example:

```
license_server: {
    server_addr: "192.168.0.20",
    name: "My license"
}
```

`sim_ip_remote_addr`
: Optional string. Defines default server address for IP simulation events of all UE.

`cpu_core_list`
: Optional array. Defines the list of CPU cores indexes on which LTEUE will run. If not set, LTEUE may use all cores, refer to [cpu_core_list], page 58, for syntax. Note that the number of cores depends on Linux scheduler and LTEUE configuration.

`vrb_lib_path`
: Optional string. Path to the `vrb_dpdk.so` dynamic library file located in the delivered tarball. If present, the eNodeB uses Intel vRANBoost device for LDPC decoding. The CPU must support vRANBoost, DPDK must be installed on the machine and the vRANBoost device must be configured properly before use. This mode enables faster LDPC decoding. It can be used to lower the CPU usage of the stack or to increase the number of LDPC decoding iterations in order to improve decoding sensitivity.

`sim_events`
: Array of object. Each element defines a remote API request ([Remote API], page 59) except that `message` field is replaced by `event`.

`sim_events_loop_count`
: If set, will define `loop_count` for each event of `sim_events`, See [loop_count], page 60.

`sim_events_loop_delay`
: If set, will define `loop_delay` for each event of `sim_events`, See [loop_delay], page 60.

6.3 Radio driver configuration

`name`
: Driver name. The corresponding DLL file name is `trx_*name*.so`. It is searched in the lteue executable directory, in the path configured in the `path` property.
The following drivers are currently available:

dummy	Dummy driver. Can be used to measure the RX to TX latency.
sdr	Amarisoft PCIe SDR driver. Parameters are defined here: SDR50 (`https://tech-academy.amarisoft.com/trx_sdr.doc#TRX-driver-configuration-options`) SDR100 (`https://tech-academy.amarisoft.com/trx_sdr100.doc#TRX-driver-configuration-options`) CPRI (`https://tech-academy.amarisoft.com/trx_cpri.doc#TRX-driver-configuration-options`)
uhd	Ettus Research UHD driver for USRP N2x0, B2x0 and X3x0 series. Please check Amarisoft UHD documentation delivered within package.
lms7002m	Lime MicroSystem LimeSDR platform driver. Please check Amarisoft SDR documentation delivered within package.

If you don't have and need one of these drivers, please contact `customer@amarisoft.com` and ask for it.

6.4 Cell group configuration

A cell groups references the configuration of 1 or more cells of the same type.

Cells within same group must be synchronized at subframe/frame level.
Handovers are not allowed between cells of different groups.

To perform 5G NSA, the configuration must contain at least two groups, one of LTE type and one of NR type.

`group_type`

String. Defines cell type, can be:

`lte`	LTE category 0 to max.
`cat_m1`	Cat-M1
`nbiot`	NB-IoT
`nr`	5G NR

`tx_gain_offset`

Optional float. Set the digital TX gain (can be seen as the opposite of the TX backoff power). Warning: do not change it unless you know what you do because a too high value introduces saturation in the output.

For LTE, the default value is -12 dB in multi UE mode and -8 dB in single UE mode.
For NB-IoT the default value is always -20 dB.
For NR the default value is always -14 dB.

`tx_time_offset`

Optional integer (LTE only). Time offset (in samples) for the TX stream relative to the RX stream. It may be needed to compensate internal delays in the radio head.

`tx_pad_duration`

Optional integer (default = 23) (NR only). Duration (in 1/1.92 us units) of the zero sample burst sent before the start of the uplink burst in TDD. It corresponds to the power amplifier ramp up duration. The appropriate value depends on the radio head.

`ground_position`

Optional object needed for GNSS location estimate for LPP and/or NTN. For NTN, this position will allow the dynamic computation of the timing advance, based on satellite realtime position. Defines the geographic coordinates at the origin [0, 0, 0] in the local coordinates system in which the position in defined See [position], page 55.
Contains the following parameters:

`latitude` Float value. Range -90 to 90. Degrees of latitude.

`longitude`

Float value. Range -180 to 180. Degrees of longitude.

`altitude` Optional float value (default = 0). Range -1000m to 20km. Altitude in meters.

`cells` Array of object. Each element gives the configuration of a cell. See [Cell configuration], page 29.

`multi_ue` Boolean. If enabled, UE simulation mode is activated where multiple UEs can be run at the same time. Note that when this mode is enabled, you should adjust the `global_timing_advance` cell parameter. If set to false, the real UE mode is activated with one single instance of UE.

`cell_sync`
Optional boolean (default = true), NR only. When multiple cells are configured in the group, this parameter indicates that the cells are synchronized at the slot level. It must be set to `true` for CA or SUL operation. On the opposite, if the cells are known to have very different timing (eg in NTN scenarios), the parameter should be set to `false`.

`long_range`
Optional boolean (default = false). If true, enable a proprietary Amarisoft extension to extend the cell range (a modified eNodeB is necessary) (LTE only). This parameter applies to all the UEs in multi-UE mode.

`rel13_5` Optional boolean (default = true). If true, enable incompatible physical layer changes for NPBCH/BCCH introduced in release 13.5 (category NB1 only).

`channel_sim`
Optional boolean (default = false). If set, the UE channel simulator is enabled. It is only available in multi UE mode (`multi_ue = true`). See [channel_sim], page 50, for more information.

`pdcch_decode_opt`
Optional boolean (default = false). If set, `pdcch_decode_opt_threshold` will be used (LTE and NR).

`pdcch_decode_opt_threshold`
Optional float. `pdcch_decode_opt` must be set to true. This parameter defines an EPRE (Energy Per Resource Element) threshold relative to CRS (LTE) or SSB (NR) for PDCCH detection to save CPU time.
Use it only with high SNR (Ex: using cables) as it may prevent from decoding low power PDCCH.

`pdsch_max_its`
Optional integer (range 1 to 20, default = 6). CPU load limitation: set the maximum number of iterations of the turbo decoder (LTE only). A higher value gives a lower frame error rate but a higher CPU load.

`ldpc_max_its`
Optional integer (range 1 to 50, default = 5). CPU load limitation: set the maximum number of iterations of the LDPC decoder (NR only). A higher value gives a lower frame error rate but a higher CPU load.

`cpu_core_list`
Optional array. Defines the list of CPU cores indexes on which the cell group will run.
Refer to [cpu_core_list], page 58, for syntax.
If not set, LTEUE may use all cores, or if RF frontend driver provides NUMA nodes, they will be used.

6.5 Cell configuration

`n_antenna_dl`

Optional integer (default = 1). Range: 1 to 8. Set the number of downlink antennas. See [channel_sim], page 50, to have more information when the channel simulator is enabled. NB-IoT cells only support a single downlink antenna.

`n_antenna_ul`

Optional integer (default = 1). Range: 1 to 8. Set the number of uplink antennas. See [channel_sim], page 50, to have more information when the channel simulator is enabled. LTE and NB-IoT cells only support a single uplink antenna.

`sample_rate`

Optional float. Sample rate in MHz. It is normally automatically set depending on the radio head capabilities and selected bandwidth.
To take effect, `bandwidth` must not be set.

`rf_dl_freq`

Optional float. Override the tuning frequency in MHz for the downlink. This optional is only needed if there is a frequency translator after the SDR device.

`rf_ul_freq`

Optional float. Override the tuning frequency in MHz for the uplink. This optional is only needed if there is a frequency translator after the SDR device.

`rf_port`

Optional integer (default = automatically incremented). Define the RF port index for this cell. By default, each cell has its own RF port, but several cells can share the same RF port by setting the same `rf_port` value.
RF port sharing is supported only for NB-IoT cells belonging to the same cell group. The first cell in the `cell_list` with a given `rf_port` will set the center frequency of the SDR and shall have a `bandwidth` value accomodating all the cells sharing the RF port.

`global_timing_advance`

Optional integer. Range: -1 to 1292 (default = -1). This option is only meaningful in multiple UE mode and specifies the timing advance of the uplink relative to the downlink. The unit is `1/1.92` us for non NR cells and `1/(0.128*SCS)` us for NR cells where `SCS` is the cell subcarrier spacing in kHz. The special value -1 indicates to use the timing advance from the first received RAR. See [Multiple UE case], page 7, for more information.

`apply_ta_commands`

Optional boolean (default = false). This option is only meaningful in multiple UE mode and allows the UE to follow the TA commands received from the network. This option is only available for NB-IoT and NR UEs. It is not possible to have both `delay_sim` and `apply_ta_commands` set to true. See [Multiple UE case], page 7, for more information.

`forced_pci`

Optional integer (default = -1). Force the selected Physical Cell Identity. The default value -1 indicates to select the first detected PCI. This parameter is currently not available for NB-IoT cells.

`tx_gain_offset`

Optional float. If set, overrides group value: [tx_gain_offset], page 28.

`ntn_n_ta_ue`

Optional float (default = -1). If positive, specify a constant NTA_UE in microseconds when computing Timing Advance in NTN.

If negative or left out and if the cell is in a NTN band, `ground_position` in the cell group is mandatory.

`ntn_eci_aligned_ecef`
Optional boolean (default = false). If set to true, the orbital parameters (read from SIB31 in NB-IoT or SIB19 in NR) are understood with the ECI reference frame aligned with the ECEF frame at the current epoch.
If set to false, the ECI reference is aligned with the J2000 vernal equinox.

`ntn_service_dl_freq`
Optional integer (default = 0). NR only. If non zero, this parameter sets the value in Hz of the actual DL frequency used on the satellite service link when it is different from the DL frequency specified by `dl_nr_arfcn`.

`ntn_service_ul_freq`
Optional integer (default = 0). NR only. If non zero, this parameters sets the value in Hz of the actual UL frequency used on the satellite service link.

`ntn_internal_model`
Optional enumeration: auto, orbital, state_vectors (default = auto). Choose the internal propagation model for the satellite position, either based on keplerian orbital elements or based on a force-model integration of the state vectors. When set to `auto`, the propagation model will depend on the content of SIB19, either OrbitalElements or StateVectors.

`cpu_core_list`
Optional Array. Defines the core affinity of the digital signal processing engine (Physical layer) for both UL and DL of the cells associated to this rf_port (See [cpu_core_list], page 58).

`cpu_core_list_ul`
Optional Array. Defines the core affinity of the digital signal processing engine (Physical layer) for UL of the associated cell(s). If set, overrides `cpu_core_list`.

`cpu_core_list_dl`
Optional Array. Defines the core affinity of the digital signal processing engine (Physical layer) for DL of the associated cell(s). If set, overrides `cpu_core_list`.

`nb_threads`
Optional number. If set, forces the number of threads used by the digital processing engine for DL or UL of the associated cell(s).

`nb_threads_ul`
Optional number. If set, forces the number of threads used by the digital processing engine for UL of the associated cell(s). If set, overrides `nb_threads`.

`nb_threads_dl`
Optional number. If set, forces the number of threads used by the digital processing engine for DL of the associated cell(s). If set, overrides `nb_threads`.

`cpu_numa_list`
Optional array of integers. Each integer represent a NUMA node index. If set will, digital processing engine will use the list of defined NUMA nodes for its memory usage.
If this field is not set but `cpu_core_list` is defined, LTEUE will select the NUMA nodes associated to the affected cores. This means that most of the time this parameter shouldn't be set. The only relevant case is when a NUMA node has no RAM bank connected, you may use this parameter to select the closest NUMA node with memory.

`s72` Optional object. If set, this cell port will use ORAN split 7.2 TRX API to send data to the radio unit.
This section has the following properties:

`rtc_id` Integer. RTC id.

`ud_comp_hdr`
Optional integer (default = 0). Set User Data compression header configuration. Can be `0` for no compression, `0x81` for BF8, `0x91` for BF9, `0xc1` for BF12 or `0xe1` for BF14.

`port_mapping`
Optional array of integers. If set, allows to map UE antenna to different RU port.
Each number represents the RU port ID used for the antenna in ORAN packets.
This array must have same number of elements as the maximum between DL antenna count and UL antenna count.
Each RU port must be set once in the array. Ex:

```
port_mapping: [1, 2, 4, 0],
```

Means UE will use RU port 1 for the first antenna, RU port 2 for the second antenna... By default, it is set to `[0, 1, 2, ... ]`

`port_mapping_dl`
Optional array of integers. Same as `port_mapping` except that it applies only for DL antenna and the array must have same number of elements as DL antenna count.

`port_mapping_ul`
Optional array of integers. Same as `port_mapping` except that it applies only for UL antenna and the array must have same number of elements as UL antenna count.

`port_mapping_prach`
Optional array of integers. Same as `port_mapping` except that it applies only for the PRACH ORAN packets.

`gen_prb0` Optional boolean (default = false). If true, numPrbc of U-Plane ORAN section will be set to 0 when all ressources blocks are used and exceed 255.
If set to false and number of ressources blocks exceed 255, multiple ORAN sections will be generated.

`cp_dl` Optional boolean (default = true). If false, LTEUE is not expecting DL-Control plane packets and will assume DU has to send full spectrum for every DL symbols.

`relative_symbol`
Optional boolean (default = false). In case of section type 3, start symbol of both control and data packet will start at 0, i.e relative to time_offset

`debug` Optional boolean (default = false). If true, mode information will be displayed in logs. May have an impact on performances.

The following parameters are available if `group_type` is not set to "nr":

`dl_earfcn`
Range: 0 to 262143. Set the DL EARFCN. See `https://www.sqimway.com/lte_band.php` to convert between the center frequency and EARFCN.

`ul_earfcn`

Optional. Range: 0 to 262143. Set the UL EARFCN. If not provided, the default DL/UL gap is used (i.e. ul_earfcn = dl_earfcn + 18000 for FDD).

`bandwidth`

Optional number. Defines LTE bandwidth and can be 20, 15, 10, 5, 3 or 1.4.
If omitted, `sample_rate` has to be set.

`sample_rate_num`

Optional integer (LTE only). Main sample rate used for the LTE signal processing in 1.92 MHz units (hence 3 means 5.76 MHz). It is normally automatically set depending on the radio head capabilities and selected bandwidth. If the resulting rate is different from `sample_rate`, a fractional sample rate interpolator is used to convert the sample rate (this is only possible with a 15kHz SCS without ORAN split 7.2).

`prach_delay`

Optional integer (LTE and NR only). Range: 0 to 1920 (default = 0). This option specifies the PRACH delay relative to the other uplink signals in TA units. The same PRACH delay is applied to all the UEs of the cell. This option is useful to simulate an arbitrary PRACH timing advance in multiple UE mode.

`sync_id`

Optional integer (default = 0). Cells with same `sync_id` must be synchronized in time (Same Frame/SubFrame numbers). To allow non synchronized cells within a group, set different `sync_id` for each cell. Only applicable to LTE UEs.
Note that for proper CA operation, the PCell and SCells must be synchronized.

The following parameters are available if `group_type` is set to `"nr"`:

`band`

Integer (range 0 to 1024). NR band.

`dl_nr_arfcn`

Integer (range 0 to 3279165). Set the DL NR-ARFCN. See `https://www.sqimway.com/nr_band.php` to convert between the center frequency and NR-ARFCN.

`ul_nr_arfcn`

Integer (range 0 to 3279165). Set the UL NR-ARFCN. See `https://www.sqimway.com/nr_band.php` to convert between the center frequency and NR-ARFCN.

`subcarrier_spacing`

Integer (15, 30, 60, 120). Set the cell subcarrier spacing.

`ssb_subcarrier_spacing`

Optional integer (15, 30, 120, 240). Set the SSB subcarrier spacing. If absent, the value from `subcarrier_spacing` is used instead.

`ssb_nr_arfcn`

Optional integer (range 0 to 3279165). Set the SSB NR-ARFCN. See `https://www.sqimway.com/nr_band.php` to convert between the center frequency and NR-ARFCN. If absent, the value from `dl_nr_arfcn` is used instead.

`ssb_case_c`

Optional boolean. Set to true if case C must be used instead of case B for 30 kHz SSB SCS. The default value depends on the selected frequency band (see 3GPP TS 38.101-1 table 5.4.3.3-1).

`bandwidth`

Optional integer (range 3 to 400). Cell bandwidth.

`n_rb_dl` Optional integer (range 20 to 275). Number of DL resource blocks. Used if `bandwidth` is absent.

`rx_to_tx_latency`
Optional integer (Range 2 to 32, default = 4). Minimum allowed latency in slots between RX and TX.
This parameter will bound the minimum k1 and k2 parameter allowed by the system. Increasing the value will improve performances, especially in case of radio frontend underflows.

`pdcch_log_filename`
Optional string. Log the PDCCH decoding attempts to the `pdcch_log_filename` file. It is useful only when debugging the PHY layer. Do not enable it in other cases as it may generate a large log file and may degrade the UE performance.

`udc_port` Optional integer. Selects the UDC port used for the cell. Cells aggregated with the same UDC device, will use the same udc_port number.

`tx_power_offset`
Optional float. If set add an offset in dB to any TX signal power information such as 't spl'. Useful when placing an attenuator (negative value) or a power amplifier (positive value) after the radio frontend TX output.

6.6 UE configuration

6.6.1 Virtual USIM

The following parameters configure the virtual USIM:

`mnc_nb_digits`
Optional enumeration: 2, 3 (default = 2). Set the number of digits in home network MNC.

`imsi` Optional string. Shall be present if `nai` is absent. Set the IMSI.

`nai` Optional string applicable to 5G only.
Shall be present if `imsi` is not set. Set the Network specific identifier-based SUPI.

`sim_algo` Optional enumeration. xor, milenage or tuak (default = xor). Set the USIM authentication algorithm. Note: test USIM cards use the XOR algorithm.

`sqn` Optional string (6 byte hexadecimal string). Default = `"000000000000"`. Set the initial sequence number. For the XOR algorithm, the actual value does not matter. For the Milenage or TUAK algorithm, a sequence number resynchronization is initiated if the sequence number does not match the one stored in the USIM.

`K` String. Set the user secret key (as a 16 bytes hexadecimal string, or eventually 32 bytes hexadecimal string for TUAK).

`op` Optional string. Operator key (as a 16 byte hexadecimal string). When the Milenage authentication algorithm is used, either `op` or `opc` must be set.

`opc` Optional string. Operator key preprocessed with the user secret key (as a 16 byte hexadecimal string). When the Milenage authentication algorithm is used, either `op` or `opc` must be set.

`r` Optional array of 5 integers (range: 0 to 127). Allows to customize the r1 to r5 parameters when Milenage authentication algorithm is used. If the array is not present, the default values (as defined in 3GPP TS 35.206) are used.

`c` Optional array of 5 strings. Each value contains a 16 byte hexadecimal string. Allows to customize the c1 to c5 parameters when Milenage authentication algorithm is used. If the array is not present, the default values (as defined in 3GPP TS 35.206) are used.

`top` Optional string. Operator key (as a 32 byte hexadecimal string). When the TUAK authentication algorithm is used, either `top` or `topc` must be set.

`topc` Optional string. Operator key preprocessed with the user secret key (as a 32 byte hexadecimal string). When the TUAK authentication algorithm is used, either `top` or `topc` must be set.

`keccak_iter`

Optional integer (range: 1 to MAX_INT). Allows to customize the number of Keccak permutations performed when using the TUAK authentication algorithm. If the item is not present, the default value 1 (as defined in 3GPP TS 35.231) is used.

`cag_info_list`

Optional array. Subscribed CAG information list. Each element of the array contains:

`plmn` String (5 or 6 digits).

`cag_id_list`

Array of 1 to 12 integers (range 0 to 4294967295) giving the list of the allowed CAG-Identifiers.

`cag_only_ind`

Optional boolean (default = FALSE). Indication that the UE is only allowed to access 5GS via CAG cells.

`csg_info_list`

Optional array of objects. Subscribed CSG information. Each element of the array contains:

`plmn` String (5 or 6 digits).

`csg_id_list`

Array of integers in range 0 to 0x7FFFFFF. Allowed CSG id list in the PLMN.

`res_len` Optional integer (default = 8). Defines length of response in bytes during authentication. For TUAK authentication algorithm, the RES length configured on UE and network side must match and the value must be 4, 8 or 16 bytes long.

`preferred_plmn_list`

Optional array. Each element of the array contains a PLMN string (5 or 6 digits) ordered by decreasing priority. Can be present only if none of plmnwact, oplmnwact and ehplmn is present.

`plmnwact` Optional array containing the list of user controlled PLMN with access technology (refer to 3GPP 31.102 chapter 4.2.5) used by the NAS PLMN selection procedure. Each element of the array contains a PLMN and the allowed access technologies, ordered by decreasing priority:

`plmn` String (5 or 6 digits).

`access_techno`

Array of enumeration: eutra_nb, eutra_wb, eutra, nr.

`oplmnwact`
: Optional array containing the list of operator controlled PLMN with access technology (refer to 3GPP 31.102 chapter 4.2.53) used by the NAS PLMN selection procedure. See [plmnwact], page 35, for coding.

`hplmnact`
: Optional array of elements listed in decreasing priority order, giving the access technologies of the home PLMN the UE will consider when searching for the HPLMN (refer to 3GPP 31.102 chapter 4.2.54). Each element is an array of enumeration: eutra_nb, eutra_wb, eutra, nr. Example:

```
hplmnact:
[
  ["nr", "eutra_nb"],
  ["eutra_wb"]
]
```

`ehplmn`
: Optional array containing the equivalent home PLMN list (refer to 3GPP 31.102 chapter 4.2.84) used by the NAS PLMN selection procedure. Each element of the array contains a PLMN string (5 or 6 digits) ordered by decreasing priority.

`lrplmnsi`
: Optional enumeration: last_registered, hplmn_or_last_registered (default = last_registered). Gives the Last RPLMN Selection Indication as defined in 3GPP 31.102 chapter 4.2.86.

`access_control_classes`
: Optional array of integers containing the assigned access control classes (refer to 3GPP 31.102 chapter 4.2.15 EFACC).
Default value is [0, 1, 2, 3, 4, 5, 6, 7, 8, 9].
Each element of the array is an access class number in range 0-9 or 11, 12, 13, 14, 15.

`uac_access_identities`
: Optional array of enumeration: "mps", "mcs". Gives the configuration information pertaining to access identities allocated for specific high priority services. If "mps" is present in the array, the UE is configured for Multimedia Priority Service, if "mcs" is present in the array, the UE is configured for Mission Critical Services, see specified in 3GPP 31.102 chapter 4.4.11.7 EFUAC_AIC;

`eab`
: Optional boolean (default = false). Indicates whether the UE applies EAB (extended access barring). Equivalent parameter in the USIM is 'Extended access barring' in EFNASCONFIG (see 31.102 chapter 4.2.94 EFNASCONFIG).

6.6.2 SIM card reader

`external_sim`
: Optional boolean (default = false). If set, will try to use SIM card reader instead previous parameters. (Uses the PCSC lite library)

`sim_reader_index`
: Optional integer (range 0 to 1024). If *external_sim* is set, this allow to select SIM card reader if several are plugged.

6.6.3 UE parameters

6.6.3.1 Common parameters

The following parameters are available for UEs of all types, unless stated otherwise.

`imeisv`
: Optional string. Set the International Mobile station Equipment Identity and Software Version Number. If not set, will be automatically generated.

`as_release`
: Optional integer (default = 8). Define the Access Stratum release for UE capabilities. Releases 8 to 18 are supported.

`nas_5gs`
: Optional boolean (default = false). When set to true, the LTE or NB-IoT UE will connect to a 5G core network through a ng-eNB.

`ue_category`
: Optional integer (-2 to 13) or string (default = 4). Set the UE category/type. The string values `m1`, `nb1`, `nb2` or `nr` are also accepted. For backward compatibility, -1 means category M1 and -2 means category NB1. Category M1 or NB1 need at least `as_release` 13. Category NB2 needs at least `as_release` 14. Category NR needs at least `as_release` 15 and sets the UE in 5G SA mode.

  All UEs must be either category >= 0, category M1, NB-IoT or NR.

`long_drx`
: Optional boolean (default = true). When set to false, the UE does not indicate supporting DRX in its capabilities (LTE, NR).

`short_drx`
: Optional boolean (default = true). When set to false, the UE does not indicate supporting short DRX cycles in its capabilities (LTE, NR).

`t3324`
: Optional integer. Value in seconds of the T3324 information element sent by the UE in the NAS Attach Request, Tracking Area Update Request and Registration Request messages.

`sprt_support`
: Optional boolean (default = false). Set strictly periodic registration timer support in 5GMM MICO indication IE.

`t3412`
: Optional integer. Value in seconds of the T3412 extended information element sent by the UE in the NAS Attach Request and Tracking Area Update Request messages, or requested T3512 information element sent by the UE in the NAS Registration Request message. `t3324` parameter must be set.

`edrx_params`
: Optional integer (range 0 to 255). If present, UE will declare support for extended idle mode DRX. This integer is encoded according to 3GPP TS 24.008 chapter 10.5.5.32.

`dl_ca`
: Optional boolean (default = true). When set to false, the UE does not report BandCombinations with DL CA in its capabilities.

`ul_ca`
: Optional boolean (default = true). When set to false, the UE does not report BandCombinations with UL CA in its capabilities.

`ca_filter_bc_3x101`
: Optional boolean (default = true). When set to false, the UE will report all the possible band combinations (in the SupportedBandCombinationList IE of the UE capabilities) based on the `cells` array, regardless of their support in 3GPP TS 36.101/38.101 v18.2.0.
  When set to true, only the combinations supported in 3GPP specification will be reported.

`ca_intraband`
: Optional enumeration: all, contiguous_only, non_contiguous_only (default = all). Controls how the UE reports the intraband CA band combinations.

`wus_support`
: Optional boolean (default = true). When set to false, the UE does not indicate supporting wake up signal in NB-IoT and Cat-M1.

`wus_edrx_min_time_offset`
: Optional enumeration: 40, 240, 1000, 2000 (default = 40). Minimum time offset (in ms) between the end of WUS transmission and beginning of paging occasion when UE is in eDRX.

`gwus_paging_probability`
: Optional enumeration: -1, 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100 (default = -1: group WUS not activated). Requested paging probability of the UE used to determine the WUS group to which belongs the UE.

`apn`
: Optional string. If set, this APN will be used for UE attachment as default APN.

`authentication`
: Optional enumeration: `none`, `pap`, `chap` or `eap` (default set to `none`). Defines the APN authentication mechanism used during attachment.
`eap` is applicable to 5G only.

`username`
: Optional string (up to 100 characters) containing the user name used for `pap`, `chap` or `eap` authentication.

`password`
: Optional string (up to 100 characters) containing the password used for `pap`, `chap` or `eap` authentication.

`tun_setup_script`
: Optional string. Set the path of the shell script to set up the virtual network interface (Path can be absolute or relative to config file).
Script is called for each PDN with following parameters:

1. UE ID
2. PDN unique ID (starts from 0)
3. Interface name
4. IPv4 address
5. IPv4 DNS address
6. IPv6 link local address
7. IPv6 DNS address
8. `tun_script_param` associated to UE
9. APN/DNN name

followed by those optional informations:

- –cid <CID> PDN connection ID associated to `pdn_connect` command
- –mtu <MTU size> Interface MTU size

A sample script is provided: `ue-ifup`.
It configures a network namespace for each UE.
As a result you can set IP traffic this way:

```
ip netns exec <UE ID> ping 192.168.3.1
```

If no script is given, no virtual network interface is created.
If `rue_addr` is set, this parameter will be forwarded to remote UE server.
When this mode is on, only `ext_app` simulation is available.

`tun_script_param`
: Optional string. Parameter passed to `tun_setup_script` for this UE.

`tun_ifname`
: Optional string. If `tun_setup_script` is set, defines the name of the TUN interface for the first PDN. The TUN interface may have been created outside of the program.

`rue_addr`
: Optional string. Address of remote UE server. See [Remote UE], page 93. Default port is 2152.

  Note that `tun_setup_script` is mandatory.

`sim_events`
: Array of object. Each element defines a remote API request ([Remote API], page 59) except that `message` field is replaced by `event`.
  `ue_id` is implicitely set to this UE so that the message may apply to it.

`sim_events_loop_count`
: If set, will define `loop_count` for each event of `sim_events`, See [loop_count], page 60.

`sim_events_loop_delay`
: If set, will define `loop_delay` for each event of `sim_events`, See [loop_delay], page 60.

`sim_ip_remote_addr`
: Optional string. Defines default server address for IP simulation events

`attach_request_with_dummy_guti`
: Optional boolean (default = false). If true, attach procedure will be done with a dummy GUTI instead of IMSI.

`emergency_attach`
: Optional boolean (default = false). If true, attach procedure will be for emergency services.

`imei_attach`
: Optional boolean (default = false). If true, attach procedure will be done with an IMEI instead of an IMSI.

`ue_usage_setting`
: Optional enumeration: none, voice, data (default = data). Sets the UE usage setting as defined in 3GPP TS 24.008 chapter 10.5.5.28 and 3GPP TS 24.501 chapter 9.11.3.55.

`voice_domain_preference_eutran`
: Optional enumeration: cs_only, ims_ps_only, cs_preferred, ims_ps_preferred (default = ims_ps_only). Sets the voice domain preference for E-UTRAN as defined in 3GPP TS 24.008 chapter 10.5.5.28.

`cp_ciot_opt`
: Optional boolean (default = false). If true, enable control plane CIoT optimization support. It can be used if the network supports it.

`cp_edt`
: Optional boolean (default = false). If true and control plane CIoT is supported, enable CP-EDT support.

`attach_without_pdn`
: Optional boolean (default = false). If true ;
  For LTE, enable attach without PDN for data transfer via SMS. It can be used if

the network supports it.
For 5G, the UE will not set the Follow-On request bit in the initial registration message and will not request any PDU session establishment, unless a call to `pdn_connect` is performed.

`attach_pdn_type`
Optional enumeration: ipv4, ipv6, ipv4v6, unstructured, ethernet (default = ipv4v6).
For LTE, selects the PDN type for the PDN connectivity request message piggybacked in attach request.
For 5G, selects the PDU session type for the PDU session establishment request sent after the UE registration.
Note that IPv6 and Ethernet require the use of the tun interface.

`attach_pdn_ims`
Optional boolean (default = false). Specifies if the PDN connectivity request message piggybacked in attach request or the first PDU session establishment request sent after the UE registration is for IMS or not.

`combined_eps_imsi_attach`
Optional boolean (default = false). If true, attach procedure type will use combined EPS/IMSI.

`sms_centre_address`
Optional object used to configure the SMS centre address. Contains the following parameters:

`type_of_number`
Optional enumeration "unknown", "international", "national" (default = "unknown"). SMS centre address type of number.

`numbering_plan`
Optional enumeration "unknown", "national", "private" (default = "unknown"). SMS centre address numbering plan identification.

`number` String. Contains optional '+' at first position followed by a maximum of 20 digits. SMS centre address number.

`use_security_context_for_registration`
Optional boolen (default = true). If false, the UE will never use its current security context for the EMM attach request or initial 5GMM registration request message.

`eutra_voice_support`
Optional boolean (default = true). If true, UE declares voice support in EUTRA RRC capabilities.

`nr_voice_support`
Optional boolean (default = true). If true, UE declares voice support in NR RRC capabilities.

`lpp_support`
Optional boolean (default = true). Indicates the support of LPP in the UE.

`cipher_algo_bitmap`
Optional integer (default = 0xe0). Defines the ciphering algorithms advertised by the UE in the NAS UE Network Capability information element. The coding of the field is per 3GPP TS 24.301 chapter 9.9.3.34: most significant bit is for EEA0/5G-EA0, followed by EEA1/5G-EA1, EEA2/5G-EA2 and EEA3/5G-EA3.

If encryption is necessary, AES (EEA2/5G-EA2) would give the best performance if your CPU supports the AES NI Intel instruction set (use "grep -o aes /proc/cpuinfo" in Linux to see if AES is displayed). In this case, it is recommended to configure the network to use EEA2. Alternatively, the EEA2 usage could be forced at the network side by setting the supported algorithms to EEA0 and EEA2 in the bitmap, if there is no other solution.

`integ_algo_bitmap`
: Optional integer (default = 0xe0). Defines the integrity algorithms advertised by the UE in the NAS UE Network Capability information element. The coding of the field is per 3GPP TS 24.301 chapter 9.9.3.34: most significant bit is for EIA0/5G-IA0, followed by EIA1/5G-IA1, EIA2/5G-IA2 and EIA3/5G-IA3.

For best performance, use AES (EIA2/5G-IA2) if your CPU supports the AES NI Intel instruction set (use "grep -o aes /proc/cpuinfo" in Linux to see if AES is displayed). In this case, it is recommended to configure the network to use EIA2. Alternatively, the EIA2 usage could be forced at the network side by setting the supported algorithms to EIA0 and EIA2 in the bitmap, if there is no other solution.

`cell_index`
: Optional integer. Defines the cell index (index of the object in the `cells` array) to be used for the initial cell selection. If `rrc_initial_selection` is set to true, `cell_index` is ignored.

`rrc_initial_selection`
: Optional boolean (default = true). It set to true, RRC initial cell selection according to 3GPP 36.304 and 38.304 is performed and `cell_index` is ignored.

`rrc_sel_resel`
: Optional boolean (default = true). It set to false, RRC cell selection and reselection according to 3GPP 36.304 and 38.304 are not performed.

`ue_count`
: Optional integer (default = 1). Create n user entries by incrementing the IMSI and K. All other properties would stay the same for the UEs. Note that you should as well create the same user entries at the MME side with their corresponding IMSI and K values (For Amarisoft MME, you can use the `count` parameter).

`rsrq_offset`
: Optional float (default = 0). Add an offset in dB to the measured RSRQ.

`apply_ul_mbr`
: Optional boolean (default = true). If set to true, the UE restricts the UL traffic to the configured non-GBR AMBR or GBR MBR/MFBR.

`pdsch_fer`
: Optional float. Range 0 to 1 (default = 0). If different from zero, simulate a given Frame Error Rate (or BLER) for each PDSCH decoding. The FER is simulated only when the PDSCH are successfully decoded. Note: `pdsch_fer` overrides the FER coming from the UE channel simulator.

6.6.3.2 LTE specific parameters

`dl_category`
: Optional integer (0 to 15, 20). If present, set the DL UE category for a release 12 UE or for the secondary RAT in a NR UE with s1 mode support. Not all combinations of DL UE category and UL UE category are allowed (see Table 4.1A-6 in 3GPP TS 36.306). DL category 20 is only supported for release 15 UE.

`ul_category`

Optional integer (0 to 13, 16 to 20). Must be present if `dl_category` is present. Set the UL UE category for a release 12 UE or for the secondary RAT in a NR UE with s1 mode support. UL category 16 or higher is only supported for release 14 UE.

`drx_cycle`

Optional integer (32, 64, 128 or 256 for LTE and NR UEs, 32, 64, 128, 256, 512 or 1024 for NB-IOT UEs). If set, the UE indicates a UE specific DRX cycle in the EPS NAS Attach Request or 5GS Registration Request message and uses it for paging monitoring.

`sps` Optional boolean (default = false). When set to true, the UE indicates semi-persistent scheduling support in its capabilities.

`tti_bundling`

Optional boolean (default = false). When set to true, the UE indicates TTI bundling support in its capabilities. UE with release 12 or higher will also declare support for e-HARQ-Pattern-FDD-r12 and noResourceRestrictionForTTIBundling-r12.

`half_duplex`

Optional boolean (default = false). Set UE duplex mode.

`mbms` Optional boolean (default = true). If true, MBMS is enabled.

`forced_cqi`

Optional integer. Range 0 to 15 (default = -1). If >= 0, forces the CQI reported to eNB.

`forced_ri`

Optional integer. Range -1 to 8 (default = 0). If >= 1 force the Rank Indicator (RI) reported to eNodeB. 0 indicates to compute the RI (currently it is always set to the maximum number of layers determined from the transmission mode, number of downlink antennas and UE capabilities). -1 forces the RI to cycle between 1 and the maximum number of layers.

`forced_pmi`

Optional integer. Range -1 to 15 (default = -1). If >= 0, force the Precoding Matrix Indicator (PMI) in the CSI reports. Otherwise the PMI is randomly selected.

`max_mimo_layers_dl`

Optional integer (default = 0). Range 0 to 8. If != 0, the maximum number of DL MIMO layers in the UE capabilities is set to min(max_mimo_layers_dl, n_antenna_dl).

`random_ap_subband_cqi`

Optional boolean (default = false). If true, send random aperiodic subband CQI (reporting modes 3-0 and 3-1). The wideband CQI is not random.

`random_ap_subband_pmi`

Optional boolean (default = false). If true, send random aperiodic subband PMI (reporting mode 1-2). The wideband PMI is not random.

`forced_ce_level`

Optional integer. Range -1 to 3 (default = -1). If >= 0, force the coverage extension level (UE Category M1 or NB-IoT only).

6.6.3.3 NB-IoT specific parameters

`multi_tone`

Optional boolean (default = true). If true, UE declares support for multi tone.

`multi_carrier`

Optional boolean (default = false). If true, UE declares support for multi carriers. This option is only compatible in UE simulation mode (`multi_ue:true`).

`bandwidth` or `sample_rate` should be large enough to fit the the expected non-anchor carriers around the anchor carrier. There is no need to specify the DL/UL EARFCN of the non anchor carriers. If the UE is also release 14 or higher, NPRACH and paging on non anchor carrier is supported.

`two_harq` Optional boolean (default = false). If true, UE declares support for two HARQ processes (NB-IoT category NB2 only).

`interf_rnd`

Optional boolean (default = false). If true, UE declares support for interference randomisation feature (NB-IoT Rel 14 only). If UE declares multi carrier support, the value defaults to true.

6.6.3.4 NR specific parameters

`en_dc_support`

Optional boolean (default = false). Activates EN-DC support to perform 5G NSA. Need at least `as_release` 15 and `ue_category` 1.

`n1_support`

Optional boolean applicable to a LTE UE only (default = false). Activates the N1 mode in the UE.

`nr_need_for_gaps`

Optional boolean applicable to a LTE UE only (default = true). Indicates if gaps are required to measure NR cells while in RRC connected state in an EUTRA cell.

`s1_support`

Optional boolean applicable to a NR UE only (default = false). Activates the S1 mode in the UE.

`srb3_support`

Optional boolean (default = false). Activates SRB3 support for EN-DC UEs.

`rrc_inactive_support`

Optional boolean (default = false). Activates RRC Inactive mode support (SA only).

`sul_support`

Optional boolean (default = false). Activates Supplementary Uplink support. The cell used as supplementary uplink should be defined in the NR cell_group and transmit at least a valid SSB, similarly to carrier aggregation operation. `multi_ue` also needs to be set to true.

`uplink_tx_switch_option`

Optional enumeration : none, switched, dual, both (default = none). If set different from `none` and if `ul_ca` is false, the UE will advertise Uplink Tx Switch band combinations and set the corresponding value for uplinkTxSwitching-OptionSupport-r16.

`bwp_switching_delay`

Optional enumeration : type1, type2 (default = type1). bwp-SwitchingDelay capability.

`ecc_params`

Optional object. Set the parameters used for concealing the subscription permanent identifier (SA only).

`scheme` Optional enumeration: null, A, B (default = null). Set the protection scheme.

`home_nw_public_key`
Conditional string. Shall be absent if scheme is null, and present otherwise. Set the home network public key. Length shall be 32 bytes for profile A and 33 for profile B (for profile B, the compressed mode is used).

`home_nw_public_key_id`
Integer in range 0 to 255. Set the home network public key identifier related to the provided home network public key. Value 0 is only valid for null scheme protection.

`routing_indicator`
Optional string (default = `"0"`). 1 to 4 numerical digits. Set the home network routing indicator.

`nr_forced_cqi`
Optional integer. Range 0 to 15 (default = -1). If >= 0, forces the CQI reported in the CSI reports.

`nr_forced_ri`
Optional integer. Range -1 to 8 (default = 0). If >= 1 force the Rank Indicator (RI) in the CSI reports.

`nr_forced_pmi_i1`
Optional integer (default = -1). If >= 0, force the Precoding Matrix Indicator i1 in the CSI reports. The subparts of the i1 (i1_1, i1_2 and i1_3) are extracted from the value and cropped accordingly based on the network-configured codebook and reported rank indicator.

`nr_forced_pmi_i2`
Optional integer (default = -1). If >= 0, force the Precoding Matrix Indicator i2 in the CSI reports.

`nr_forced_li`
Optional integer (default = -1). If >= 0, force the Layer Indicator in the CSI reports with CRI_RI_LI_PMI_CQI report quantity.

`nr_max_mimo_layers_dl`
Optional integer (default = 0). Range 0 to 8. If != 0, the maximum number of DL MIMO layers in the UE capabilities is set to min(nr_max_mimo_layers_dl, n_antenna_dl).

`nr_max_mimo_layers_ul`
Optional integer (default = 0). Range 0 to 8. If != 0, the maximum number of UL MIMO layers in the UE capabilities is set to min(nr_max_mimo_layers_ul, n_antenna_ul).

`ptrs_density_recommendation_dl`
Optional object. Specify the `ptrs-DensityRecommendationSetDL` NR UE RRC capability for all the supported bands. The following object properties are defined:

`frequency_density`
Optional array of 2 integers (default = `[1, 176]`).

`time_density`
Optional array of 3 integers (default = `[0, 0, 0]`).

`default_pdu_session_snssai`

Optional object (SA only). S-NSSAI provided by the UE during the establishment of the default PDU session.
If not present, no S-NSSAI is provided.

- `sst` Integer (range 0-255). Slice Service Type.
- `sd` Optional integer (range 0-0xFFFFFE). Slice Differentiator.

`default_nssai`

Optional array (SA only). Default configured NSSAI as defined in 3GPP TS 23.501.
Each entry will set a S-NSSAI value as defined below:
See [default_pdu_session_snssai], page 45,

`snssai_credentials`

Optional array (SA only). Each entry will set the credentials of a given S-NSSAI as defined below:

- `snssai` S-NSSAI value. See [default_pdu_session_snssai], page 45,
- `username` String (up to 100 characters) containing the user name used for NSSAA.
- `password` String (up to 100 characters) containing the password used for NSSAA.

`eap_tls`

Optional object applicable to SA only. Shall be present if EAP-TLS method is supported by the UE.
It contains the following objects:

- `certificate`
  Define the user certificate filename.
- `private_key`
  Define the user private key filename.
- `ca_certificate`
  Define the CA certificate filename. It contains a list of root certificates to authenticate the server.

`snpn_access_mode`

Optional boolean applicable to SA only (default = false). Activates the SNPN mode in the UE. This mode is configurable dynamically when the UE is powered off using the remote api `config_set`.

`allowed_snpn`

Optional object (SA only). Set the SNPN id to select in SNPN mode.

- `plmn` String (5 or 6 digits).
- `nid` Network Identifier as defined in 23.003 12.7 Stand-Alone Non-Public Network Identifier. Contains the following parameters:
  - `value` String (10 hexadecimal digits). NID value.
  - `assignment_mode`
    Optional enumeration ("self", "coordinated_1", "coordinated_2"). Default value is "self".

`cag_info_list`

Optional array (SA only). Preconfigured CAG information list as defined in 3GPP TS 23.501 5.30.3.3 UE configuration. Each element of the array contains:

- `plmn` String (5 or 6 digits).

`cag_id_list`
Array of 1 to 12 integers (range 0 to 4294967295) giving the list of the allowed CAG-Identifiers.

`cag_only_ind`
Optional boolean (default = false). Indication that the UE is only allowed to access 5GS via CAG cells.

`redcap` Optional enumeration (normal redcap, eredcap). Set the UE type in SA. The `as_release` needs to be at least 17 for `redcap` and 18 for `eredcap`.

`eredcap_reduced_bb_bw`
Optional boolean (default = true). Defines if the eRedCap UE is with reduced baseband bandwidth or not.

`half_duplex`
Optional boolean (default = false). Set a RedCap UE as half-duplex. Value is ignored if `redcap` is not set.

6.6.4 Power control

The following parameter control the UE power:

`power_control_enabled`
Optional boolean. If set, UE power control is enabled. The uplink messages are transmitted with the power specified by the standard.

The default value of `power_control_enabled` is `true` if the UE channel simulator is enabled and otherwise `false`.

If the UE power control is disabled, the uplink messages are transmitted with a constant EPRE (Energy Per Resource Element) = `EPRE_max` determined by `tx_gain_offset` (digital gain) and [tx_gain], page 23, (RF interface TX gain).

When the UE power control is enabled, the EPRE (Energy Per Resource Element) is limited by `EPRE_max` so that there is no digital saturation even if the uplink bandwidth is shared between several UEs.

The `sat` column of the `t g` monitor command counts the number of times the UE simulator had to limit the TX power of an uplink signal (e.g. PUCCH or PUSCH) to `EPRE_max`. It indicates that the actual UE TX power was lower than the specified one.

`power` Optional float (only meaningful if UE power control is enabled). Set the maximum UE transmit power in dBm. The default value is 23 dBm.

Note that the actual maximum TX power may be lower because of the limited power of the RF interface and because of the uplink EPRE limitation (see the `power_control_enabled` parameter).

`power_min`
Optional float (default = -40) (only meaningful if UE power control is enabled). Set the minimum UE transmit power in dBm.

6.6.5 RF test mode

The following parameters configure the UE RF test mode:

`test_mode`
Optional Object. If present, enable the UE RF test mode. In this mode, the UE automatically goes to RRC connected mode with a default configuration after acquiring the System Information. Then it listens to PDCCH to initiate PDSCH

or PUSCH transmissions. It also transmits PUCCH ACK/NACK and listens to PHICH.

The following properties are available for LTE UEs:

`rnti` Integer. Range 0 to 65535. Select the C-RNTI.

`trans_mode`
Integer. (LTE only) Range 1 to 9. Select the PDSCH transmission mode.

`dl_256qam`
Optional boolean. (LTE only) Enable the DL 256QAM MCS table.

The following properties are available for NB-IoT UEs:

`rnti` Integer. Range 0 to 65535. Select the C-RNTI.

`npdcch_uss_n_rep_max`
Integer. Range: 1 to 2048. Maximum number of repetition for the User Search Space (USS) NPDCCH.

`npdcch_uss_start_sf`
Enumeration: 1.5, 2, 4, 8, 16, 32, 48, 64. Used to compute of the period of the USS NPDCCH by multiplying it to `npdcch_uss_n_rep_max`.

`npdcch_uss_offset`
Integer. Range: 0 to 3. USS NPDCCH start offset in 8th of the USS NPDCCH period.

`ul_sc_spacing`
Enumeration: 0, 1. Select the subcarrier spacing used by the UE. 0 = 3.75 KHz subcarriers, 1 = 15 KHz subcarriers.

`timing_advance`
Integer (0 to 1282). Initial timing advance in 1/1.92 microsecond.

The following properties are available for NR UEs:

`rnti` Integer. Range 0 to 65535. Select the C-RNTI.

`dmrs_type_a_pos`
Integer. Range 2 to 3. dmrs-TypeA-Position parameter.

`ssb_pos_bitmap`
String. SSB position bitmap in bits (4, 8 or 64 bits depending on the DL frequency).

`ssb_period`
Enumeration (5, 10, 20, 40, 80, 160). SSB periodicity in ms.

`pdcch` Object containing the following parameters:

- `rb_start` Integer. Range 0 to 274. PDCCH resource block start.

- `l_crb` Integer. PDCCH resource block length.

- `duration` Integer. Range 1 to 3. PDCCH duration.

- `n_candidates`
  Array of 5 integers. Enumeration: 0, 1, 2, 3, 4, 5, 6, 8. nrofCandidates parameters for each aggregation level (1, 2, 4, 8, 16).

`pdsch` Object containing the following parameters:

`start_symb`
Integer. Range 0 to 3. PDSCH start symbol.

`n_symb` Optional integer. Range 3 to 14-`start_symb`, default = 14-`start_symb`. Number of symbols for PDSCH.

`k0` Integer. Range 0 to 3. Delay in slots from DCI to PDSCH.

`pucch` Object containing the following parameters:

`pucch_group_hopping`
Enumeration: neither, enable, disable. pucch-GroupHopping parameter.

`pusch` Object containing the following parameters:

`beta_offset_ack_index`
Integer. Range 0 to 15.

`n_symb` Integer. Range 4 to 14. Number of symbols for PUSCH.

`tf_precoding`
Boolean. Enable transform precoding for PUSCH (only used in DCI 0_1).

`k2` Integer. Range 0 to 7. Delay in slots from DCI to PUSCH.

`timing_advance`
Integer. Range 0 to 4095. Timing advance value in TA units.

6.6.6 SWu and NWu interface

The following parameters configure the SWu interface for communication with ePDG or NWu interface for communication with N3IWF:

`n3gpp` Optional object. Allow to configure the SWu or the NWu interface. It can contain the following object:

`bind_addr`
IP address and optional port on which the SWu/NWu connection is bound.

`server_addr`
ePDG/N3IWF address.

`server_certificate`
Optional string. Defines the ePDG/N3IWF certificate filename.

`esp_duration`
Optional integer in range 10 to 5*3600 (default = 300). Gives the duration in seconds of the ESP-Sa.

`ike_duration`
Optional integer in range 20 to 48*3600 (default = 24*3600). Gives the duration in seconds of the IKE-Sa.

`ike_encryption_algo_list`
Optional list of IKE-Sa supported encryption algorithms "aes-cbc-128" (AES CBC 128 bits key length), "aes-cbc-192" (AES CBC 192 bits key length), "aes-cbc-256" (AES CBC 256 bits key length), "aes-gcm-128-16" (AES GCM 128 bits key length and 16 bytes ICV),

"aes-gcm-256-16" (AES GCM 256 bits key length and 16 bytes ICV), "3des", "blowfish", "aes-ctr-128" (AES CTR 128 bits key length), "aes-ctr-192" (AES CTR 192 bits key length), and aes-ctr-256 (AES CTR 256 bits key length) ordered from most preferred to least preferred.

Default value is ["aes-cbc-128", "aes-cbc-192", "aes-cbc-256", "aes-gcm-128-16", "aes-gcm-256-16", "3des", "blowfish", "aes-ctr-128", "aes-ctr-192", "aes-ctr-256"].

`ike_integrity_algo_list`

Optional list of IKE-Sa supported integrity algorithms "hmac-sha-1-96", "hmac-sha-1-160", "hmac-sha-256-128", "hmac-sha-384-192, "hmac-sha-512-256", "hmac-md5-96", "hmac-md5-128" and "aes-cmac-96" ordered from most preferred to least preferred.

Default value is ["hmac-sha-1-96", "hmac-sha-1-160", "hmac-sha-256-128", "hmac-sha-384-192", "hmac-sha-512-256", "hmac-md5-96", "hmac-md5-128", "aes-cmac-96"];

`ike_prf_list`

Optional list of IKE-Sa supported pseudo-random functions "prf-hmac-sha1", "prf-hmac-sha2-256", "prf-hmac-sha2-384", "prf-hmac-sha2-512", "prf-hmac-md5" and "prf-aes128-xcbc" ordered from most preferred to least preferred.

Default value is ["prf-hmac-sha1", "prf-hmac-sha2-256", "prf-hmac-sha2-384, "prf-hmac-sha2-512", "prf-hmac-md5", "prf-aes128-xcbc"].

`ike_dh_group_list`

Optional list of IKE-Sa supported Diffie-Hellman groups "group_1", "group_2", "group_5", "group_14", "group_15", "group_16", "group_17", "group_18", "group_19", "group_22", "group_23" and "group_24" ordered from most preferred to least preferred.

Default value is ["group_5", "group_14", "group_15", "group_16", "group_17", "group_18", "group_19", "group_22", "group_23", "group_24"].

`esp_encryption_algo_list`

Optional list of ESP-Sa supported encryption algorithms "null", "aes-cbc-128" (AES CBC 128 bits key length), "aes-cbc-192" (AES CBC 192 bits key length), "aes-cbc-256" (AES CBC 256 bits key length), "aes-gcm-128-16" (AES GCM 128 bits key length and 16 bytes ICV), "aes-gcm-192-16" (AES GCM 192 bits key length and 16 bytes ICV), "aes-gcm-256-16" (AES GCM 256 bits key length and 16 bytes ICV), "3des", "blowfish", "aes-ctr-128" (AES CTR 128 bits key length), "aes-ctr-192" (AES CTR 192 bits key length), aes-ctr-256 (AES CTR 256 bits key length), "encr-null-auth-aes-gmac-128" (ENCR_NULL_AUTH_AES_GMAC 128 bits key length), "encr-null-auth-aes-gmac-192" (ENCR_NULL_AUTH_AES_GMAC 192 bits key length) and "encr-null-auth-aes-gmac-256" (ENCR_NULL_AUTH_AES_GMAC 256 bits key length) ordered from most preferred to least preferred.

Default value is ["null", "aes-cbc-128", "aes-cbc-192", "aes-cbc-256", "aes-gcm-128-16", "aes-gcm-192-16", "aes-gcm-256-16", "3des", "blowfish", "aes-ctr-128", "aes-ctr-192", "aes-ctr-256", "encr-null-auth-aes-gmac-128", "encr-null-auth-aes-gmac-192", "encr-null-auth-aes-gmac-256"].

`esp_integrity_algo_list`
: Optional list of ESP-Sa supported integrity algorithms "null", "hmac-sha-1-96", "hmac-sha-1-160", "hmac-sha-256-128", "hmac-sha-384-192, "hmac-sha-512-256", "hmac-md5-96", "hmac-md5-128" and "aes-cmac-96" ordered from most preferred to least preferred.
Default value is ["null", "hmac-sha-1-96", "hmac-sha-1-160", "hmac-sha-256-128", "hmac-sha-384-192", "hmac-sha-512-256", "hmac-md5-96", "hmac-md5-128", "aes-cmac-96"].

`esp_dh_group_list`
: Optional list of ESP-Sa supported Diffie-Hellman groups "none", "group_1", "group_2", "group_5", "group_14", "group_15", "group_16", "group_17", "group_18", "group_19", "group_22", "group_23" and "group_24"ordered from most preferred to least preferred.
This list is used for rekeying ESP-Sa. Default value is ["none", "group_5", "group_14", "group_15", "group_16", "group_17", "group_18", "group_19", "group_22", "group_23" and "group_24"].

`multiple_auth_support`
: Optional boolean (default = false). Indicates if multiple UE authentications is supported in the UE (see 3GPP 33.402 chapter 6.5).

`tun_setup_script`
: Optional string. Set the path of the shell script to set up the virtual network interface (Path can be absolute or relative to config file). Script is called for each PDN with following parameters:

1. UE ID
2. type (SWU/XWU)
3. APN name
4. interface name
5. IPv4 address
6. IPv6 link local address
7. remote address

6.7 Channel simulator

6.7.1 Introduction

The UE channel simulator simulates an AWGN or fading channel for each UE. It is available in multi UE mode for LTE or NR UEs.

On the downlink side, depending on the simulated UE path loss and fading model, the channel simulator modifies the PER (Packet Error Rate) of PDSCH and PDCCH and updates the measured RSRP and CSI. On the uplink side, the signal level is modified according to the path loss and the fading model is applied.

The path loss of each UE is computed according to the corresponding UE and cell positions and the channel and antenna models.

The channel simulator is enabled with the cell group `channel_sim` parameter. It can optionally be disabled with the per-UE parameter `channel_sim` parameter.

6.7.2 Per cell parameters

When the channel simulator is enabled, the following additional parameters may be specified for each cell:

`n_antenna_dl`
: Optional integer (default = 1). Set the number of simulated UE downlink antennas.

`n_antenna_ul`
: Optional integer (default = 1). Set the number of simulated UE uplink antennas.

`n_antenna_dl_rf`
: Optional integer (default = `n_antenna_dl`). Specifies the number of eNB/gNB DL RF antennas for this cell. For LTE cells, it is usually equal to the number of PBCH antennas. When using a `parabolic_panel` antenna, it must be equal to (p*n1*n2).

`n_antenna_ul_rf`
: Optional integer (default = `n_antenna_ul`). Specifies the number of eNB/gNB UL RF antennas for this cell. When using a `parabolic_panel` antenna, it must be equal to (p*n1*n2).

`position`
: Array of 1 to 3 floats. X, Y and Z coordinates of the cell antenna, in meters. If less than 3 elements are provided, the remaining coordinates are set to zero. For the `satellite` antenna type, the position corresponds to the beam center on the ground.

`antenna`
: Object. Cell antenna parameters:

  `type`
  : Enumeration: isotropic, parabolic, parabolic_panel, satellite. An `isotropic` antenna radiates the same intensity in all directions. A `parabolic` antenna sends a beam in a given direction (attenuation in dB = `min(max_attenuation, 12*(phi/beam_width)^2)` where `phi` is the radiation angle. A `parabolic_panel` antenna is the same as a parabolic antenna except that it has several N1 antenna elements in the Y direction, N2 antenna elements in the Z direction and P polarisation channels per antenna elements. See 3GPP TR 38.901 section 7.3 for more information. A `satellite` antenna emulates a satellite link for NTN operation and is valid only for a NR cell.

  `attenuation`
  : Optional enumeration (urban, vacuum, atmospheric, custom, custom_freq). Set the propagation loss model. It must be provided for the `satellite` antenna. For the other antenna types it is set to `urban` by default. The following values are available:

    `urban`
    : The path loss in dB is computed from the 3GPP urban model as `A + B * log10(d)` where `d` is the distance in meters between the UE and the cell antenna, `A` = 15.3 and `B` = 37.6.

    `custom`
    : Same as `urban` except than `A` and `B` can be set.

    `custom_freq`
    : Same as `custom` with an additional frequency term. The path loss is defined as `A + B * log10(d) + 20 * log10(f)` where `f` is the downlink frequency in Hz.

    `vacuum`
    : Free space path loss depending only on the downlink frequency and distance.

`atmospheric`
: Only available for satellite. Same as `vacuum` but with an additional atmospheric attenuation term depending on the satellite elevation.

`attenuation_A`
`attenuation_B`
: Optional float. Parameters for the `custom` and `custom_freq` attenuation.

The following parameters are for the `parabolic`, `parabolic_panel` and `satellite` antennas:

`max_attenuation`
: Optional float (default = 20). Maximum attenuation in dB when the UE is out of the beam coverage

The following parameters are for the `parabolic` and `parabolic_panel` antennas:

`beam_width`
: Optional float (default = 70). Horizontal beam half-width in degrees.

`vertical_beam_width`
: Optional float (default = 70). Vertical beam half-width in degrees.

`orientation`
: Float (range = -180 to 180). Orientation of the antenna in the X-Y plane in degress.

`elevation`
: Optional float (range = -90 to 90, default = 0). Elevation of the antenna in degrees.

The following parameters are for the `parabolic_panel` antenna:

`n1` Integer. Number of antenna elements in the Y direction.

`n2` Optional integer (default = 1). Number of antenna elements in the Z direction.

`p` Optional integer (range = 1 to 2, default = 2). Number of polarisation channels per antenna element.

`d1` Optional float (default = 0.5). Distance between the antenna elements in the Y direction in wavelength units.

`d2` Optional float (default = 0.5). Distance between the antenna elements in the Z direction in wavelength units.

The RF channel index c corresponding to an antenna element can be computed as c=(k*n2+j)*n1+i with 0 <= i < n1, 0 <= j < n2, 0 <= k < p and 0 <= c < p*n2*n1. i is the antenna element index in the Y direction, j is the antenna element index in the Z direction and k is the index of the polarisation channel.

The following parameters are for the `satellite` antenna:

`beam_width`
: Optional float (default = 5). Conical beam half-width in degrees.

`ephemeris_from_sib`
: Optional boolean (default = true). If true, the satellite orbit will be determined based on SIB19 reception. If false, the orbit information needs to be explicitely given by the `tle_filename` or `ephemeris` parameters.

`tle_filename`

Optional string. If `ephemeris_from_sib` is false, specifies a TLE file to describe satellite orbit.

`ephemeris`

Optional object. If `ephemeris_from_sib` is false and `tle_filename` is absent, this parameter describes explicitely the orbital elements of the satellite. The ephemeris configuration is understood in a fixed ECI reference frame aligned with the J2000 vernal equinox, like a TLE configuration.
Contains the following parameters:

- `eccentricity`

  Float value. Range 0 to 0.99. Eccentricity, unitless

- `inclination`

  Float value. Range 0 to π. Inclination, in radians. Value between $\pi/2$ and π will be encoded as $-\pi/2$ to -1 in RRC ASN.1 representation.

- `semi_major_axis`

  Float value. Semi-major axis, in meters.

- `longitude`

  Float value. Range 0 to 2π. Longitude of the ascending node, in radians.

- `periapsis`

  Float value. Range 0 to 2π. Argument of periapsis, in radians.

- `anomaly` Float value. Range 0 to 2π. Mean anomaly of the satellite on its orbit at `epoch`, in radians.

- `epoch` Optional string. Epoch for the `anomaly` parameter, formatted "YYYY-MM-DDTHH:MM:SS[.mmm]" (ISO 8601 format) in UTC time.

`feeder_mode`

Optional enumeration (`cell_center`, `explicit_position`, `explicit_delay`, default = `explicit_position` if `feeder_position` is set, `cell_center` otherwise). Specifies how the feeder link delay is simulated, either by setting the feeder ground position at the cell `position` parameter, setting an explicit value for feeder ground position (see `feeder_position`) or setting an explicit value for the delay (see `feeder_delay`).

`feeder_position`

Optional object to specify the coordinate of the feeder link ground station when `feeder_mode` is set to `explicit_position`. The feeder link ground position is used to compute the full delay of the satellite link (service link + feeder link).
Contains the following parameters:

- `latitude` Float value. Range -90 to 90. Degrees of latitude.

- `longitude`

  Float value. Range -180 to 180. Degrees of longitude.

`altitude` Optional float value (default = 0). Range -1000m to 20km. Altitude in meters.

`feeder_delay`

Optional float to specify an explicit fixed delay for the feeder link, in microseconds, when `feeder_mode` is set to `explicit_delay`. Typically for regenerative scenario when there is no feeder link, set the delay to 0.

`gain` Optional float (default 0.0). Configures the directional gain (in dBi) of the satellite antenna. Any additional directional gain on the UE side antenna can also be added.

`ref_signal_power`

Float. Reference signal power in dBm. Should normally have the same value as `SIB2.referenceSignalPower` (LTE) or `SIB1.ss-PBCH-BlockPower` (NR).

`ul_power_attenuation`

Float. Real uplink analog attenuation (in dB) actually present between the UE simulator and the eNodeB. It is used to compute the TX power of each UE TX message so that the eNodeB receives them at the power level computed by the channel simulator.

The UE TX power is calculated as

```
pTX = p0 - path_loss + ul_power_attenuation
```

where p0 is the simulated TX power (as per 3GPP power control) and path_loss is calculated by channel simulator.

The `ul_power_attenuation` should be set low enough so that there is no power saturation and high enough so that the DAC range of the RF interface is correctly used.

The `ul_power_attenuation` should be lowered until there is no saturation in the `sat` column of the `t g` monitor command while the virtual UEs are transmitting. The `sat` column counts the number of times the UE simulator had to limit the TX power of an uplink signal (e.g. PUCCH or PUSCH) so that it does not give a saturated output on the DAC. These saturations do not degrade the signal like the saturations at the sample level (see `t spl` monitor command) but they indicate that the UE received power at the eNodeB will be lower than expected by the channel simulator.

The same can be achieved with the [tx_gain], page 23, the `tx_gain` should be set high enough so that there is no power saturation (higher analog power requires less digital power) and low enough so that the DAC range of the RF interface is correctly used.

With the PCIe SDR board, it is suggested to start with a `tx_gain` at maximum value (90 dB) and 60 dB analog attenuation. The actual value depends on the simulated UE path loss.

`delay_sim`

Optional boolean (default = true). When the UE channel simulator is enabled, select whether the propagation delays are simulated. They are computed according to the distance between the UE and the cell antenna. The propagation delay is simulated by adding a cyclic shift to the corresponding uplink signal.

6.7.3 Per UE parameters

When the channel simulator is enabled, the following additional parameters may be specified for each UE:

`channel_sim`
: Optional boolean. If cell group `channel_sim` parameter is set, allow to override its value on a UE basis.

`position`
: Array of 1 to 3 floats. X, Y and Z coordinates of the UE in meters. If less than 3 elements are provided, the remaining coordinates are set to zero.

`initial_radius`
: Optional float (default = 0). If larger than zero, set the UE position randomly in a disc of `initial_radius` meters centered on `position`.

`speed`
: Optional float (default = 0). UE speed in kilometers per hour.

`direction`
: Optional float (default = 0). the UE speed vector direction in degrees.

`elevation`
: Optional float (default = 0). the UE speed vector elevation in degrees.

`noise_spd`
: Optional float (default = -174). Noise spectral density in dBm/Hz.

`min_distance`
: Optional float. If set, when UE is moving and its distance to origin is less than this value, UE will bounce according to `bounce` parameter.

`max_distance`
: Optional float. If set, when UE is moving and its distance to origin is more than this value, UE will bounce according to `bounce` parameter.

`bounce`
: Optional string (default = random). Defines bouncing mode when `min_distance` or `max_distance` are reached.

Mode	Description
random	Get back with a random angle
back	Get back in opposite direction
normal	Get back while maintaining the same angle to the normal

`channel`
: Object. Parameters of the downlink channel. If `ul_channel` is not present, the same parameters are used for the uplink channel. Each UE has separate uplink and downlink channel simulator instance to each connected cell. The following properties are available:

`type` Simulated channel type:

Type	Description
awgn	Additive White Gaussian Noise channel. When there are more than one input or output antennas, the channel matrix $a_{i,j}$ is set such as $a_{i,i \bmod n_{tx}} = 1$.
static	Static channel model from 3GPP TS 36.101 and TS 38.101-4.
epa	Extended Pedestrian A model from 3GPP TS 36.101.
eva	Extended Vehicular A model from 3GPP TS 36.101.
etu	Extended Typical Urban model from 3GPP TS 36.101.
mbsfn	MBSFN channel from 3GPP TS 36.101.
tdla30	TDLA30 channel from 3GPP TS 38.141 (TDLA with 30 ns delay spread).
tdlb100	TDLB100 channel from 3GPP TS 38.141 (TDLB with 100 ns delay spread).
tdlc300	TDLC300 channel from 3GPP TS 38.141 (TDLC with 300 ns delay spread).
tdld30	TDLD30 channel from 3GPP TS 38.141 (TDLD with 30 ns delay spread).
ntn_tdla100	NTN-TDLA100 channel from 3GPP TS 38.101-5.
ntn_tdlc5	NTN-TDLC5 channel from 3GPP TS 38.101-5.
tdla, tdlb, tdlc, tdld or tdle	TDL channels from 3GPP TS 38.901 section 7.7.2. Note that the TDL channels from 3GPP TS 38.141 slightly differ from the ones defined in 3GPP TS 38.901 when using the same delay spread.

`freq_doppler`

Optional float. For non AWGN channels, sets the doppler frequency, in Hz. Note that is has no relation with the configured UE speed which is only used to update the UE position.

`delay_spread`

Set the delay spread in ns for TDL channels (`tdla`, `tdlb`, `tdlc`, `tdld` and `tdle`).

`mimo_correlation`

Optional enumeration. Set the MIMO correlation matrix for non AWGN channels.

Allowed values:

Value	Description
low	Low correlation matrix (identity matrix) (3GPP TS 36.101 section B.2.3.2).
medium	Medium correlation matrix with uniform linear array (3GPP TS 36.101 section B.2.3.2).
high	High correlation matrix with uniform linear array (3GPP TS 36.101 section B.2.3.2).
cross_pol_medium	Medium correlation matrix with cross polarized antennas (3GPP TS 38.101-4 section B.2.3.2).

cross_pol_high	High correlation matrix with cross polarized antennas (3GPP TS 38.101-4 section B.2.3.2).

`A` Optional float (default = 15.3)

`B` Optional float (default = 37.6). If `A` or `B` are provided, the UE path loss in dB is computed as `A + B * log10(d)` where `d` is the distance in meters between the UE and the cell antenna. Otherwise, the UE path loss is computed from the cell antenna `attenuation` parameter.

`ul_channel`

Optional object. If present, specifies the parameters of the uplink channel. Otherwise the uplink channel has the same parameters as the downlink channel. This object contains the properties `type`, `freq_doppler` and `mimo_correlation` with the same definition as in the `channel` object.

DL and UL channel reciprocity on TDD NR serving cells is enabled provided the following conditions are met:

- `ul_channel` is not present
- `n_antenna_ul` is less or equal to `n_antenna_dl`
- `n_antenna_ul_rf` is equal to `n_antenna_dl_rf`

When channel reciprocity is enabled, SRS antenna switching is accurately simulated.

When channel reciprocity is not enabled or when the UE channel simulator is not used, SRS configured with antenna switching are sent to the n-th UL antenna assuming the UL antennas are connected to the same cables as the DL antennas so that they share the same channel propagation. In this case, SRS antenna switching can only be accurately simulated if `n_antenna_ul` is equal to `n_antenna_dl`.

6.7.4 Known limitations and implementation details

- The fading channels are implemented in the frequency domain. Hence the channel simulation is accurate only if the doppler frequency (`freq_doppler`) is small regarding to the subcarrier spacing.
- For the uplink, the channel is not modified between the symbol repetitions of a given PRACH.
- For the downlink, the PER of the PDCCH is currently computed assuming an AWGN channel. However the fading channel is accurately modeled for PDSCH and CSI measurements.
- In LTE, the PDSCH PER for UE specific transmission modes (TM7/TM8/TM9/TM10) is not accurately modeled. For TM9/TM10, the CSI measurement is currently modeled from the CRS (cell reference signal) instead of the CSI-RS.

7 CPU/Cores configuration

For optimal performances LTEUE will use multiple cores. Those cores can be spread on multiple CPUs (Multi socket) as long as Linux operating system makes them available.

By default, LTEUE will try to find the most suitable amount of necessary cores depending on the total number of available cores and the desired radio configuration (Mainly depending on number of cells, on their bandwidth and number of antenna).

For optimization purpose, this can be manually defined as explained in this chapter.

7.1 Hyperthreading

We strongly recommend to disable CPU hyperthreading.
The main reason is that LTEUE is memory intensive and any process running on a twin of a core used by the process may steal its cache resources, leading to performance degradation.

If you use Amarisoft automatic installation, you should disable it during the installation process.
For optimal performances, you may disable hyperthreading in the BIOS.

If you want to keep hyperthreading on for other processes, you may configure Linux to avoid scheduling other processes on the twin of the cores used by LTEUE using core isolation.

7.2 Core restriction cores

LTEUE will restrict its core usage to the list of cores affected to the process by the OS at startup.

If the process is launch with a dedicated core list, such as what `tasket` program will do, the software relies on it and will tries to use only specified cores.

In the case where cores would have been isolated by kernel at boot time, those cores won't be used by default.
If you want to use them, you will need to use `taskset` program (or equivalent) to prevent this restriction.

7.3 Affinity

You can force core affinity of the process externaly (Ex: using taskset program) or use `cpu_core_list` array.

Each element will represent cores to use or not, with following syntax:

`Number` Represent the core index to use (Same as processor information in /proc/cpuinfo).

`String`

String	Description
<a>	where <a> is a number, represents the core index to use.
*	all cores (excluding hyperthreaded twins) will be added to the list.
numa<n>	all cores related to NUMA node <n> will be added
<a>-<b>	all cores between core index <a> and core index <b> (included) will be added. <b> can be "last" representing the index of the last core.

!<cores> remove all the cores defined by <core> where <code> can have the other string syntax defined above.

By default, only non hyperthreaded cores will be used. To select hyperthreaded core twins, use number syntax or start string by `"ht:"`.
Ex: `"ht:*"` will select all cores including hyperthreaded twins.

The `cpu_core_list` can be defined at top level of your configuration file to force the global affinity of the process or for dedicated sections.

Examples:
Let's assume we have a CPU with 8 hyperthreaded cores (16 logical cores).

```
cpu_core_list: ["*", "!4"]
```

Will assign cores 0, 1, 2, 3, 5, 6 and 7

```
cpu_core_list: ["5-last", "ht:12-last"]
```

Will assign cores 5, 6, 7, 12, 13, 14, 15

7.4 Memory

On NUMA (Non Uniform Memory Access) CPU architecture, you may improve performances by assigning NUMA nodes to different digital processing engines.
This is the case when you have multiple sockets on your motherboard or with AMD processor.
Note that by default NUMA nodes are hidden by BIOS to the OS so you may change your BIOS configuration to use them.

For each digital processing engine, you should assign NUMA nodes for memory and for core affinity that has the shortest path.
In other words, when you affect cores to a DSP engine, you should ensure that the assigned cores are located on the fewest NUMA nodes possible and if needed select manually your NUMA node for memory (See [cpu_numa_list], page 31).

As the DSP engine communicates huge amount of memory to the radio frontend, you may select same NUMA nodes as your radio frontend.
If you use Amarisoft PCIe radio frontends, you can check which NUMA node is used by checking kernel traces (dmesg) when inserting kernel driver.
Ex:

```
sdr PCI device 6c:00.0 assigned to minor 5, type=RF_SDR100_Slave (rev 1) numa=1 dma:1ch 64b
```

8 Remote API

You can access LTEUE via a remote API.
Protocol used is WebSocket as defined in RFC 6455 (`https://tools.ietf.org/html/rfc6455`).

Note that Origin header is mandatory for the server to accept connections.
This behavior is determined by the use of `nopoll` library.
Any value will be accepted.

To learn how to use it, you can refer to our the following tutorial (`https://tech-academy.amarisoft.com/RemoteAPI.html`).

8.1 Messages

Messages exchanged between client and LTEUE server are in strict JSON format.

Each message is represented by an object. Multiple message can be sent to server using an array of message objects.

Time and delay values are floating number in seconds.

There are 4 types of messages:

- Request

  Message sent by client.
  Common definition:

  `message` String. Represent type of message. This parameter is mandatory and depending on its value, other parameters will apply.

  `message_id`
  Optional any type. If set, response sent by the server to this message will have same message_id. This is used to identify response as WebSocket does not provide such a concept.

  `start_time`
  Optional float. Represent the delay before executing the message.
  If not set, the message is executed when received.

  `absolute_time`
  Optional boolean (default = false). If set, `start_time` is interpreted as absolute.
  You can get current clock of system using `time` member of any response.

  `standalone`
  Optional boolean (default = false). If set, message will survive WebSocket disconnection, else, if socket is disconnected before end of processing, the message will be cancelled.

  `loop_count`
  Optional integer (default = 0, max = 1000000). If set, message will be repeated `loop_count` time(s) after `loop_delay` (From message beginning of event).
  Response will have a `loop_index` to indicate iteration number.

`loop_delay`
Optional number (min = 0.1, max = 86400). Delay in seconds to repeat message from its `start_time`. Mandatory when `loop_count` is set > 0.

- Notification

  For some API, intermediate message may be sent by server before reception of response.
  Common definition:

  `message` String. Same as request.

  `message_id`
  Optional any type. Same as in request.

  `time` Number representing time in seconds of the message start, relative to the beginning of the process.
  Useful to send command with absolute time.

  `notification`
  String. Notification purpose

  `utc` Number representing UTC seconds (local clock) when the response has been generated.

- Response

  Message sent by server after any request message has been processed.
  Common definition:

  `message` String. Same as request.

  `message_id`
  Optional any type. Same as in request.

  `time` Number representing time in seconds of the message start, relative to the beginning of the process.
  Useful to send command with absolute time.

  `utc` Number representing UTC seconds (local clock) when the response has been generated.

  `absolute_time`
  Optional string. If `absolute_time` has been set and message is reaching LTEUE too late, this field is present and set to `late`.

- Events

  Message sent by server on its own initiative.
  Common definition:

  `message` String. Event name.

  `time` Number representing time in seconds.
  Useful to send command with absolute time.

8.2 Startup

When WebSocket connections is setup, LTEUE will send a first message with name set to `com_name` and type set to UE.

If authentication is not set, message will be `ready`:

```
{
    "message": "ready",
    "type": "UE",
    "name": <com_name>,
    "version": <software version>,
    "product": <Amarisoft product name (optional)>
}
```

If authentication is set, message will be `authenticate` :

```
    {
        "message": "authenticate",
        "type": "UE",
        "name": <com_name>,
        "challenge": <random challenge>
    }
```

To authenticate, the client must answer with a `authenticate` message and a `res` parameter where:

```
    res = HMAC-SHA256( "<type>:<password>:<name>", "<challenge>" )
```

`res` is a string and HMAC-SHA256 refers to the standard algorithm (`https://en.wikipedia.org/wiki/HMAC`)

If the authentication succeeds, the response will have a `ready` field set to `true`.

```
    {
        "message": "authenticate",
        "message_id": <message id>,
        "ready": true
    }
```

If authentication fails, the response will have an `error` field and will provide a new challenge.

```
    {
        "message": "authenticate",
        "message_id": <message id>,
        "error": <error message>,
        "type": "UE",
        "name: <name>,
        "challenge": <new random challenge>
    }
```

If any other message is sent before authentication succeeds, the error `"Authentication not done"` will be sent as a response.

8.3 Errors

If a message produces an error, response will have an error string field representing the error.

8.4 Sample nodejs program

You will find in this documentation a sample program: `ws.js`.
It is located in `doc` subdirectory.
This is a nodejs program that allow to send message to LTEUE.
It requires nodejs to be installed:

```
    dnf install nodejs npm
    npm install nodejs-websocket
```

Use relevant package manager instead of NPM depending on your Linux distribution.

Then simply start it with server name and message you want to send:

```
./ws.js 127.0.0.1:9002 '{"message": "config_get"}'
```

8.5 Common messages

`config_get`
Retrieve current config.

Response definition:

`type` Always "UE"

`name` String representing server name.

`logs` Object representing log configuration.
With following elements:

- `layers` Object. Each member of the object represent a log layer configuration:
  - `layer name`
    Object. The member name represent log layer name and parameters are:
    - `level` See [log_options], page 22,
    - `max_size` See [log_options], page 22,
    - `key` See [log_options], page 22,
    - `crypto` See [log_options], page 22,
    - `payload` See [log_options], page 22,
    - `rep` Optional boolean. See [log_options], page 22,
    - `dci_size` Optional boolean. See [log_options], page 22,
    - `csi` Optional boolean. See [log_options], page 22,
    - `cell_meas` Optional boolean. See [log_options], page 22,
    - `cch` Optional boolean. See [log_options], page 22,
    - `ntn` Optional boolean. See [log_options], page 22,
    - `plmn` Optional boolean. See [log_options], page 22,
    - `signal` Optional boolean. See [log_options], page 22,
- `count` Number. Number of bufferizer logs.
- `rotate` Optional number. Max log file size before rotation.

`rotate_count`
: Optional number. Max log count before rotation.

`path`
: Optional string. Log rotation path.

`bcch`
: Boolean. True if BCCH dump is enabled (eNB only).

`mib`
: Boolean. True if MIB dump is enabled (eNB only).

`locked`
: Optional boolean. If `true`, logs configuration can't be changed with `config_set` API.

`cells`
: Object. List of objects (numbered by cell index) containing the following members:

`pci`
: Optional integer. Physical cell ID. Not present if the cell is not synchronized.

`dl_earfcn`
: Integer. Downlink EARFCN.

`mode`
: Optional numeration: FDD, TDD. Operation mode.

`n_rb_dl`
: Integer. Number of downlink resource blocks.

`uldl_config`
: Optional integer. TDD subframe assignment. Only present if `mode` is "TDD".

`sp_config`
: Optional integer. TDD special subframe pattern. Only present if `mode` is "TDD".

`ul_earfcn`
: Optional integer. Uplink EARFCN. Present once SIB2 is read.

`ul_carrier_freq_offset`
: Optional integer. NB-IoT uplink carrier frequency offset in multiple of 2.5 kHz. Present once SIB2 is read.

`n_rb_ul`
: Optional integer. Number of uplink resource blocks. Present once SIB2 is read.

`counters`
: Object. List of counters, with following sub members:

`messages`
: Object. Each member name is the message name and its value is its occurence.
To get list of message, type *cevent help msg* in LTEUE monitor.

`errors`
: Object. Each member name is the error name and its value is its occurence.
To get list of message, type *cevent help error* in LTEUE monitor.

`rx_channels`
: Array of objects. Each entry contains the following members:

`gain`
: Float. Cell gain in dB.

`freq` Float. Receive frequency in MHz.

`rtx_channels`
Array of objects. Each entry contains the following members:

`gain` Float. Cell gain in dB.

`freq` Float. Transmit frequency in MHz.

`port` Integer. RF port index.

`config_set`
Change current config.
Each member is optional.
Message definition:

`logs` Optional object. Represent logs configuration. Same structure as config_get (See [config_get logs member], page 63).
All elements are optional.
Layer name can be set to `all` to set same configuration for all layers.
If set and logs are locked, response will have `logs` property set to `locked`.

`log_get` Get logs.
This API has a per connection behavior. This means that the response will depend on previous calls to this API within the same WebSocket connection.
In practice, logs that have been provided in a response won't be part of subsequent request unless connection is reestablished. To keep on receiving logs, client should send a new `log_get` request as soon as the previous response has been received.
If a request is sent before previous request has been replied, previous request will be replied right now without considering specific min/max/timeout conditions.

Message definition:

`min` Optional number (default = 1). Minimum amount of logs to retrieve.
Response won't be sent until this limit is reached (Unless timeout occurs).

`max` Optional number (default = 4096). Maximum logs sent in a response.

`timeout` Optional number (default = 1). If at least 1 log is available and no more logs have been generated for this time, response will be sent.

`allow_empty`
Optional boolean (default = false). If set, response will be sent after timeout, event if no logs are available.

`rnti` Optional number. If set, send only logs matching rnti.

`ue_id` Optional number. If set, send only logs with matching ue_id.

`layers` Optional Object. Each member name represents a log layer and values must be string representing maximum level. See [log_options], page 22.
If *layers* is not set, all layers level will be set to *debug*, else it will be set to *none*.
Note also the logs is also limited by general log level. See [log_options], page 22.

`short` Optional boolean (default = false). If set, only first line of logs will be dumped.

`headers` Optional boolean. If set, send log file headers.

`start_timestamp`
Optional number. Is set, filter logs older than this value in milliseconds.

`end_timestamp`
Optional number. Is set, filter logs more recent than this value in milliseconds.

`max_size` Optional number (default = 1048576, i.e. 1MB). Maximum size in bytes of the generated JSON message. If the response exceeds this size, the sending of logs will be forced independently from other parameters.

Response definition:

`logs` Array. List of logs. Each item is a an object with following members:

- `data` Array. Each item is a string representing a line of log.
- `timestamp`
  Number. Milliseconds since January 1st 1970. Not present if `com_log_us` is set in configuration.
- `timestamp_us`
  Number. Microseconds since January 1st 1970. Only present if `com_log_us` is set in configuration.
- `layer` String. Log layer.
- `level` String. Log level: *error*, *warn*, *info* or *debug*.
- `dir` Optional string. Log direction: *UL*, *DL*, *FROM* or *TO*.
- `ue_id` Optional number. UE_ID.
- `cell` Optional number (only for PHY layer logs). Cell ID.
- `rnti` Optional number (only for PHY layer logs). RNTI.
- `frame` Optional number (only for PHY layer logs). Frame number (Subframe is decimal part).
- `channel` Optional string (only for PHY layer logs). Channel name.
- `src` String. Server name.
- `idx` Integer. Log index.
- `headers` Optional array. Array of strings.

`discontinuity`
Optional number. If set, this means some logs have been discarded due to log buffer overflow.

`microseconds`
Optional boolean. Present and set to true if `com_log_us` is set in configuration file.

`log_set` Add log.
Message definition:

`log` Optional string. Log message to add. If set, *layer* and *level* are mandatory.

`layer` String. Layer name. Only mandatory if *log* is set.

`level` String. Log level: *error*, *warn*, *info* or *debug*. Only mandatory if *log* is set.

`dir` Optional string. Log direction: *UL*, *DL*, *FROM* or *TO*.

`ue_id` Optional number. UE_ID.

`flush` Optional boolean (default = false). If set, flushes fog file.

`rotate` Optional boolean (default = false). If set, forces log file rotation.

`cut` Optional boolean (default = false). If set, forces log file reset.

`log_reset`

Resets logs buffer.

`license` Retrieves license file information.

Response definition:

`products` String. List of products, separated by commas.

`user` String. License username.

`validity` String. License end of validity date.

`id` Optional string. License ID.

`id_type` Optional string. License ID type. Can be `host_id` or `dongle_id`

`uid` Optional string. License unique ID.

`filename` Optional string. License filename.

`server` Optional string. License server URL.

`server_id`

Optional string. License server ID.

`quit` Terminates lteue.

`help` Provides list of available messages in *messages* array of strings and events to register in *events* array of strings.

`stats` Report statistics for LTEUE.
Every time this message is received by server, statistics are reset.
Warning, calling this message from multiple connections simultaneously will modify the statistics sampling time.

Message definition:

`samples` Optional boolean (default = false). Provide information similar to the 't spl' monitor command.

`rf` Optional boolean (default = false). Provide information similar to the 't cpu' monitor command.

Response definition:

`cpu` Object. Each member name defines a type and its value cpu load in % of one core.

`instance_id`

Number. Constant over process lifetime. Changes on process restart.

`counters` Object. List of counters, with following sub members:

- `messages` Object. Each member name is the message name and its value is its occurence.
  To get list of message, type *cevent help msg* in LTEUE monitor.

- `errors` Object. Each member name is the error name and its value is its occurence.
  To get list of message, type *cevent help error* in LTEUE monitor.

`cells` Object. Each member name is the cell ID and each value is an object representing statistics as follow:

- `dl_sched_users_min`
  Number. Downlink minimum number of scheduled UE by TTI.

- `dl_sched_users_max`
  Number. Downlink maximum number of scheduled UE by TTI.

- `dl_sched_users_avg`
  Number. Downlink average number of scheduled UE by TTI.

- `ul_sched_users_min`
  Number. Uplink minimum number of scheduled UE by TTI.

- `ul_sched_users_max`
  Number. Uplink maximum number of scheduled UE by TTI.

- `ul_sched_users_avg`
  Number. Uplink average number of scheduled UE by TTI.

- `dl_bitrate`
  Number. Downlink bitrate in bits per seconds.

- `ul_bitrate`
  Number. Uplink bitrate in bits per seconds.

- `dl_rx_count`
  Integer. Number of downlink transmitted packets (Without retransmissions).

- `ul_tx_count`
  Integer. Number of uplink transmitted packets (Without retransmissions).

- `dl_retx_count`
  Integer. Number of downlink retransmitted packets.

- `ul_retx_count`
  Integer. Number of uplink retransmitted packets.

- `dl_err_count`
  Integer. Number of downlink bad CRC packets.

- `ue_count` Number. Current number of powered on UE.

`rxtx_delay`
Object. each value is an object representing the TX-RX latency statistics (average, max and min values).

`cfo` Number. Center frequency offset in Hz.

`samples` Object. Set if `samples` has been set to true in request.
This object has the following properties:

`tx` Array of objects. Each object represents samples statistics of the antenna port.

`rms` Number. RMS of the signal in dBFS

`max` Number. Maximum sample value in dBFS

`sat` Number. Number of saturation events

`count` Number of IQ samples analyzed

`rms_dbm` Number. RMS of the signal in dBm

`rx` Array of objects. Each object represents samples statistics of the antenna port.

`rms` Number. RMS of the signal in dBFS

`max` Number. Maximum sample value in dBFS

`sat` Number. Number of saturation events

`count` Number of IQ samples analyzed

`rms_db` Number. RMS of the signal in dBm.

`register` Register client for messages generated by LTEUE. Message definition:

`register` Optional string or array of string. List of messages to register to.
Can be `ue_update`, `sms`, `non_ip_data`, `pws_msg`, `measurement_report`, `srs`, `pdsch`, `npdsch`.

`unregister`
Optional string or array of string. List of messages to unregister.
Can be `ue_update`, `sms`, `non_ip_data`, `pws_msg`, `measurement_report`, `srs`, `pdsch`, `npdsch`.

8.6 LTE messages

`pdn_connect`
Forces a connection to a PDN (LTE) or a PDU session (5G).
Message definition:

`ue_id` Integer. UE identifier.

`apn` Optional string. Access Point Name. Must be present if emergency is set to false.

`emergency`
Optional boolean (default = false). Indicates if it is an emergency PDN. Must be set to true if apn is absent.

`authentication`
Optional enumeration: `none`, `pap`, `chap` or `eap`. Default `none`. `eap` is applicable to 5GS only. Defines the authentication mechanism used for this APN.

`username` Optional string (up to 100 characters) containing the user name used for `pap` or `chap` or `eap` authentication.

`password` Optional string (up to 100 characters) containing the password used for `pap` or `chap` or `eap` authentication.

`pdn_type` Optional enumeration : `ipv4`, `ipv6`, `ipv4v6`, `unstructured` or `ethernet`. Default `ipv4v6`. Defines the PDN/PDU session type. Note that IPv6 and Ethernet require the use of the tun interface.

`ims` Optional boolean (default = false). Specifies if the PDN or PDU session is for IMS.

`pdu_session_id`
Optional integer. PDU session identity.

`always_on`
Optional boolean (default = true). Requests a non always-on PDU session if set to false (5G only).

`snssai` Optional S-NSSAI value (5G only). See [default_pdu_session_snssai], page 45,

Response definition:

`erab_id` Optional integer. Allocated ERAB identity for the corresponding default EPS bearer (LTE).

`pdu_session_id`
Optional integer. Allocated PDU session ID (5G).

`cid` Integer. Unique connection ID of the PDN connection / PDU session.

`pdn_disconnect`
Forces a PDN/PDU session deconnection.
Message definition:

`ue_id` Integer. UE identifier.

`cid` Optional integer. Unique connection ID of the PDN connection / PDU session allocated during `pdn_connect` procedure (value is set to 0 for the initial PDN connection / PDU session establishment during the registration procedure).

`apn` Optional string. Access Point Name. Must be present if `cid` is absent and if `emergency` is set to false.

`emergency`
Optional boolean (default = false). Indicates if it is an emergency PDN. Must be set to true if `cid` and `apn` are absent.

`snssai` Optional S-NSSAI value (5G only).

`rrc_reest`
Triggers a RRC reestablishment.
Message definition:

`ue_id` Integer. UE identifier.

`power_on` Switch UE on.
Message definition:

`ue_id` Integer. UE identifier.

`power_off`

Switch UE off.
Message definition:

`ue_id` Integer. UE identifier.

`n3gpp` Optional boolean (default = FALSE). Indicates if the power off is required for non-3GPP only.

`deregister`

Deregister the UE.
Message definition:

`ue_id` Integer. UE identifier.

`ue_get` Get list of UE with their states.
Message definition:

`ue_id` Optional integer. Identifier of UE to get state.
If not set, returns all UE.

`max` Optional integer. Maximum number of UE to retrieve.

`update` Optional boolean. If set to true will only return modified UE since last call with update set to true on same Web Socket connection.
If no UE have been modified, response will only occur when a UE will change or when timeout has been reached.

`timeout` Optional integer (default = 5). Time in seconds to wait before returning when no UE has changed. Only used when `update` is set to true.

Response definition:

`ue_list` Array of Object. Each object represent a UE with following parameters:

`imsi` String. UE IMSI.

`ue_id` Integer. UE identifier

`category` Integer or string. If integer, UE LTE category, else can be `m1`, `nb1`, `nb2` or `nr`.

`timing_advance`
Integer. Current timing advance.

`rnti` Integer. UE current RNTI.

`power_on` Boolean. UE power state (true = powered on, false = powered off).

`rrc_state`
String. Radio connection state, can be `disconnected`, `connecting`, `connected`, `idle` or `inactive`.

`emm_state`
String. EMM/5GMM state. In 4G, it can be `power off`, `deregistered`, `registering`, `registered`, `tracking area updating` or `unregistering`. In 5G, it can be `power off`, `deregistered`, `registering`, `registered`, `service request sending` or `deregistering`.

`cells` Array. List of cells (First one is always primary cell):

`index` Number. Index of the cell (as reported by the `config_get` message).

- pci Number. Physical cell ID.
- cqi Number. Last reported cqi.
- ri Number. Last reported ri.
- rsrp Number. RSRP of cell.
- rsrq Number. RSRQ of cell.
- snr Number. SNR of cell.
- path_loss
  Number. Current path loss estimated by the UE from RSRP and SIB reference signal level.
- sim_path_loss
  Optional number. It is present if the channel simulator is enabled. Current path loss computed by the channel model.
- cfo Integer. Center frequency offset in hertz.
- sample_rate_offset
  Number. Sample rate offset compared to the RF frontend one in ppm.

position Array of 3 floats. If the channel simulator is enabled, define the current position of the UE.

pdn_list Optional array containing the list of PDN/PDU session connections. Each element contains the following objects:

- cid Integer. Connection ID.
- apn String. Access point name.
- ipv4 Optional string. IPv4 address for this PDN connection.
- ipv6_if_id
  Optional string. IPv6 interface identifier for this PDN connection.
- mac_addr Optional string. MAC address for this PDN connection.
- pdu_session_id
  Optional integer. Applicable to 5GS only. PDU session identity.
- qos_flows
  Optional array of objects. Applicable to 5GS only. Each objects contains:
  - default Optional boolean. If present and set to true, indicates that it is the default QoS flow.
  - qfi Integer. Range: 0 to 63. QoS flow identifier.
  - drb_id Integer. Data Radio Bearer identity.

`erabs` Optional array of objects. Applicable to EPS only. Each objects contains:

> `default` Optional boolean. If present and set to true, indicates that it is the default PDN.
>
> `erab_id` Integer. EPS bearer identity.
>
> `drb_id` Integer. Data Radio Bearer identity.

`dl_bitrate`
Number. DL bitrate in bit/s (excluding transport blocks with CRC errors).

`ul_bitrate`
Number. UL bitrate in bit/s (excluding retranmissions).

`dl_rx_count`
Integer. Number of received transport blocks without CRC error.

`dl_err_count`
Integer. Number of received transport blocks with CRC errors.

`dl_retx_count`
Integer. Number of received retransmitted transport blocks (with or without CRC errors).

`ul_tx_count`
Integer. Number of sent transport blocks (first transmission only).

`ul_retx_count`
Integer. Number of retransmitted transport blocks.

`dl_mcs` Number. Average MCS used for DL.

`ul_mcs` Number. Average MCS used for UL.

`dl_rb` Number. Average DL resource blocks per allocation.

`ul_rb` Number. Average UL resource blocks per allocation.

`dl_decoder_min`
Optional number. Minimum turbo/ldpc decoder pass.

`dl_decoder_avg`
Optional number. Average turbo/ldpc decoder pass.

`dl_decoder_max`
Optional number. Maximum turbo/ldpc decoder pass.

`pending` Boolean. Set to true if `update` was set to true with `max` parameter and modified UE are remaining. You may call `ue_get` again with `update` set to true when receiving `pending`.

`counters` Object. List of counters, with following sub members:

> `messages` Object. Each member name is the message name and its value is its occurence.
> To get list of message, type *cevent help msg* in LTEUE monitor.

`errors` Object. Each member name is the error name and its value is its occurence.
To get list of message, type *cevent help error* in LTEUE monitor.

`ue_add` Add one or several UE.
Message definition:

`list` Array of object. Each object represent a UE as defined config file. See [UE configuration], page 34,

Response definition:

`info` Array of string. List of information.

`ue_del` Remove a UE.
The UE will be removed without performing any deregistration.
Message definition:

`ue_id` Integer or array of integers. UE ID(s) of the UE to remove.

Response definition:

`deleted` Integer. Number of deleted UE in case of list deletion.

`unknown` Array of integers. List of unknown UE IDs in case of list deletion.

`invalid` Array of integers. List of invalid UE IDs in case of list deletion.

`ue_del_all`
Remove all UEs.
The UEs will be removed without performing any deregistration.

`ue_move` Move a UE to a specific position. Relevant only with *channel_sim* set to true.
Message definition:

`ue_id` Integer. Identifier of UE to move.

`position` Optional array. See [position], page 55, channel simulator option.

`speed` Optional number. See [speed], page 55, channel simulator option.

`direction`
Optional number. See [direction], page 55, channel simulator option.

`elevation`
Optional number. See [elevation], page 55, channel simulator option.

`rf` Set radio frontend channels gain.
Message definition:

`tx_gain` Optional number or array of numbers. Set TX gain.
Same definition as the [tx_gain], page 23, property.

`tx_channel_index`
Optional number. If set, apply gain to specified channel only.

`rx_gain` Optional number or array of numbers. Set RX gain.
Same definition as the [rx_gain], page 23, property.

`rx_channel_index`
Optional number. If set, apply gain to specified channel only.

Response definition:

`tx_gain` Array. List of TX gain per channel.

`rx_gain` Array. List of RX gain per channel.

`rf_info` Optional string. RF driver information (depends on radio frontend).

`trx_iq_dump`

Dump baseband IQ samples (time domain) to files.
The IQ samples are stored as little endian 32 bit floating point numbers.
Real and imaginary part are interleaved: the real part (I) is written first, the imaginary one (Q) next:
I(0) `[0 ... 31]`
Q(0) `[32 ... 63]`
I(1) `[64 ... 95]`
Q(1) `[96 ... 127]`
...
I(n) `[n*64 ... n*64+31]`
Q(n) `[n*64+32 ... n*64+63]`

Message definition:

`duration` Optional value (default = 1s, max = 30s). Sets dump duration in milliseconds.

`rf_port` Optional integer or array of integer. If set, dump only the related RF port channels.

`rx_filename`

Optional string. If set defines the file where the received IQ samples will be dumped.
May contain *%d* to differentiate antenna streams (printf style).
If not set, no RX data will be dumped.

`tx_filename`

Optional string. If set defines the file where the transmitted IQ samples will be dumped.
May contain *%d* to differentiate antenna streams (printf style).
If not set, no TX data will be dumped.

`rx_channels`

Optional array of integer. Selects channel to dump. Each integer represents the global index of the channel.

`tx_channels`

Optional array of integer. Selects channel to dump. Each integer represents the global index of the channel.

`rx_header`

Optional boolean (Default = false). Set the dump mode.

If not set, only the IQ samples are written to the files. If set, add a header for each TRX read or write operation. It is followed by the corresponding IQ samples.

Header:

`timestamp`
64 bit TRX timestamp, in samples.

`count` 32 bit integer: number of following IQ samples before next header.

`tx_header`
Optional boolean (Default = false). Same as *rx_header* for TX.

Notification:
As IQ dump initialization may take some time (Memory allocation, file creation...), dumping of IQs may start some time before the command is being executed.
A notification message is sent when the IQ dump is really starting. You can base on its `time` parameter to synchronize any subsequent message.
Its notification property is `started`.

Message response:

`dump_utc` Integer. UTC time in milliseconds of the capture start

`rf_ports` Array of object representing information on each rf port capture. Defined as follow:

`sample_rate`
Integer. IQ sample rate in samples per seconds

`index` Integer. RF port index

`timestamp`
Integer. Timestamp (in IQ sample) associated with `frame/slot` start.

`frame` Integer. Frame number of slot starting at `timestamp`

`slot` Integer. Slot number of slot starting at `timestamp`

`mu` Integer. Subcarrier spacing (0, 1...)

`rx_files` Array of string representing IQ files for RX.

`tx_files` Array of string representing IQ files for TX.

`rx_overflows`
Optional integer. Number of RX lost data during catpure process

`tx_overflows`
Optional integer. Number of TX lost data during catpure process

`rx_timestamp0`
Integer. If `rx_header` mode not set, timestamp of first IQ sample in RX files.

`tx_timestamp0`
Integer. If `tx_header` mode not set, timestamp of first IQ sample in TX files.

`ext_app` Launch and external application.
Only available if *tun_setup_script* is set. Message definition:

`name` String. Session name.

`end_time` Float. End time. If external application is not over when this time is reached, a kill signal will be sent.
The command may finish before this time if external application process ends up before.

`prog` String. Name of external application to launch.
If path is not absolute, LTEUE config file path will be used.
Arguments passed to application will be:
- UE_ID
- TUN interface name
- Duration in seconds.

`args` Array of string or number that will be passed to application as argument (from 4th).

`dump_stdout`
Optional boolean (default = false). If set, external application stdout will be redirected to LTEUE stdout.
If external application is defined in [sim_events], page 39, the default value is true.

`dump_stderr`
Optional boolean (default = false). If set, external application stderr will be redirected to LTEUE stderr.
If external application is defined in [sim_events], page 39, the default value is true.

Response definition:

`output` String. Standard output of the application.

`error` String. Standard error of the application.

Start notification:
A message with notification set to *start* will be sent when application is launched.

Progress notification:
A message with notification set to *progress* will be sent with *output* as defined in response.

Example:
Message sent:

```
{
    message: "ext_app",
    message_id: 'foo',
    ue_id: 1,
    start_time: 1,
    end_time: 5,
    prog: "ext_app.sh",
    args: ["iperf -c 220.103.220.10 -i 1 -t 4"],
}
```

Start notification:

```
{
    message_id: 'foo',
    notification: 'start'
}
```

Progress notifications:

```
{
    message_id: 'foo',
    output: 'ip netns exec ue1 iperf -c 220.103.220.10 -i 1 -t 4\n',
    notification: 'progress'
}

{
    message_id: 'foo',
    output: '------------------------------------------------------------\nClient
    notification: 'progress'
}

{
    message_id: 'foo',
    output: '[ ID] Interval       Transfer     Bandwidth\n[  3]  0.0- 1.0 sec  1.
    notification: 'progress'
}

{
    message_id: 'foo',
    output: '[  3]  1.0- 2.0 sec  1.00 MBytes  8.39 Mbits/sec\n',
    notification: 'progress'
}
```

Final response:

```
{
    message: 'ext_app',
    message_id: 'foo',
    output: '[  3]  2.0- 3.0 sec   896 KBytes  7.34 Mbits/sec\n'
}
```

`sms` Send a SMS over SG.
Message definition:

`ue_id` Integer. Identifier of UE.

`dst` String. Phone number to send SMS to.

`text` String. SMS text.

`validity` Optional integer (Default = 86400). Validity period in seconds.

`status_req`
Optional boolean (Default = false). Indicates if a status report is requested.

`sms_command`
Send a SMS-COMMAND.
Message definition:

`ue_id` Integer. Identifier of UE.

`type` Enumeration: 0, 1, 2, 3. TP-Command-Type as defined in 3GPP 23.040 paragraph 9.2.3.19 TP-Command-Type:
0 = Enquiry relating to previously submitted short message 1 = Cancel Status Report Request relating to previously submitted short message 2

= Delete previously submitted Short Message 3 = Enable Status Report Request relating to previously submitted short message

`msg_number`
Integer in range 0 to 255. Parameter indicating which SM in the SC to operate on. TP-Message-Number as defined in 3GPP 23.040 paragraph 9.2.3.18 TP-Message-Number.

`dst` String. Destination Address to which the TP-Command refers. TP-Destination-Address as defined in 3GPP 23.040 9.2.3.8 TP-Destination-Address

`sms_memory`
Set SMS memory availability.
Message definition:

`memory` Boolean. If true, UE will send a RP SMMA message, else received SMS will lead to `memory capacity exceeded` error message.

`non_ip_data`
Send data over a non IP PDN or unstructured PDU session.
Message definition:

`ue_id` Integer. Identifier of UE.

`erab_id` Optional integer. ERAB identity of the non IP default bearer, as given in pdn_connect response. Mandatory for a LTE UE.

`pdu_session_id`
Optional integer. PDU session identity of the non IP PDU session, as given in pdn_connect response. Mandatory for a 5G UE.

`data` String. ASCII representation of the data hexadecimal dump.

`force_meas_report`
Force the sending of a RRC Measurement Report message.
Message definition:

`ue_id` Integer. Identifier of UE.

`meas_id` Integer. Measurement identifier.

`tau_request`
Trigger a NAS Tracking Area Update / mobility Registration Request procedure.
Message definition:

`ue_id` Integer. Identifier of UE.

`rlc_drop_rate`
Define a percentage of downlink RLC PDUs dropped.
Message definition:

`ue_id` Integer. Identifier of UE.

`rb_id` Integer. Bearer identity.

`srb` Boolean. Indicates if the bearer is for signalling or data.

`percentage`
Integer (range 0 to 100). Drop percentage.

`mbms_set` Start/stop receiving MBMS service.
Message definition:

`ue_id` Integer. Identifier of UE.

`service_list`
Array of strings. Each string should be formatted like "plmn.service_id" to start listening the given service.

`ue_activate_dedicated_bearer`
Trigger a Bearer Resource Allocation Request.
Message definition:

`ue_id` Integer. Identifier of UE.

`def_beared_id`
Integer. Default EPS bearer id.

`qci` Optional integer (range 1 to 255). QoS Class Identifier of the E-RAB.

`gbr` Optional object. Guaranted Bitrate information. List of properties:

`maximum_bitrate_dl`
Integer. Bearer maximum bitrate for downlink (in bits/s).

`maximum_bitrate_ul`
Integer. Bearer maximum bitrate for uplink (in bits/s).

`guaranteed_bitrate_dl`
Integer. Bearer guaranteed bitrate for downlink (in bits/s).

`guaranteed_bitrate_ul`
Integer. Bearer guaranteed bitrate for uplink (in bits/s).

`filters` Optional array of objects. List of TFT filters or QoS rules. Each filter has the following properties:

`direction`
Enumeration: `dl`, `ul` or `both`. Set the filter direction.

`id` Range: 0 to 15. Set the filter identifier.

`precedence`
Range: 0 to 255. Set the filter precedence. All the filters must have different precedence. 0 is the highest precedence. Note that precedence 80 is reserved for derived QOS rules in 5GS and thus will be rejected if configured.

`components`
Array of objects. Each component contains one of the following properties as described in 3GPP TS 23.060 chapter 15.3.2:

`ipv4_remote_addr`
String. Match a remote (external network entity) IPv4 address with the additional `mask` property.

`ipv4_local_addr`
String. Match a local IPv4 address with the additional `mask` property. Note that not all core networks support it (they must indicate the support of the Local address in TFT in PCO/ePCO).

`ipv6_remote_addr`
: String. Match a remote (external network entity) IPv6 address with the additional `mask` property.

`ipv6_remote_addr_prefix`
: String. Match a remote (external network entity) IPv6 address with the additional `prefix_len` property. Note that not all core networks support it (they must indicate the support of the Local address in TFT in PCO/ePCO).

`ipv6_local_addr_prefix`
: String. Match a local IPv6 address with the additional `prefix_len` property. Note that not all core networks support it (they must indicate the support of the Local address in TFT in PCO/ePCO).

`proto_id`
: Range: 0 to 255. Match against the IP protocol identifier.

`local_port`
: Range: 0 to 65536. Match against the local (UE) port.

`local_port_range`
: Array of 2 integers. Match against a local (UE) port range.

`remote_port`
: Range: 0 to 65536. Match against the remote (external network entity) port.

`remote_port_range`
: Array of 2 integers. Match against a remote (external network entity) port range.

`security_parameter_index`
: 32 bit integer. Match the ESP or AH security parameter index.

`type_of_service`
: Range: 0 to 255. Match the type of service (IPv4) or the traffic class (IPv6) field. The additional `mask` property is the corresponding mask.

`mask`
: Depends on TFT component.
If ipv4_remote_addr is set, string representing IPv4 address used as a mask to apply on packet remote address.
If ipv6_remote_addr is set, string representing IPv6 address used as a mask to apply on packet remote address.
If type_of_service is set, integer between 0 and 255 used as a mask to apply on packet tos.

`flow_label`
20 bit integer. Match the IPv6 flow label.

`prefix_len`
Range: 1 to 128. IPv6 address prefix length.

`destination_mac_addr`
String. Match the destination MAC address.

`source_mac_addr`
String. Match the source MAC address.

`802.1q_ctag_vid`
Range: 0 to 4095. Match the 802.1Q C-TAG VID.

`802.1q_stag_vid`
Range: 0 to 4095. Match the 802.1Q S-TAG VID.

`802.1q_ctag_pcp_dei`
Range: 0 to 15. Match the 802.1Q C-TAG PCP and DEI.

`802.1q_stag_pcp_dei`
Range: 0 to 15. Match the 802.1Q S-TAG PCP and DEI.

`ethertype`
Range: 0 to 65535. Match the ethertype.

`destination_mac_addr_range`
Array of 2 strings. Match the destination MAC address range. Only applicable to 5GC.

`source_mac_addr_range`
Array of 2 strings. Match the source MAC address range. Only applicable to 5GC.

Response definition:

`erab_id` Integer. Allocated ERAB identity for the corresponding dedicated EPS bearer.

`ue_bearer_resource_modification`
Trigger a Bearer Resource Modification Request for bearer modification.
Message definition:

`ue_id` Integer. Identifier of UE.

`beared_id`
Integer . EPS bearer id.

`qci` Optional integer (range 1 to 255). QoS Class Identifier of the E-RAB.

`gbr` Optional object. See [GBR], page 80.

`filters` Optional array. See [TFT], page 80.

`ue_deactivate_dedicated_bearer`
Trigger a Bearer Resource Modification Request for bearer deactivation .
Message definition:

`ue_id` Integer. Identifier of UE.

`beared_id`
Integer . EPS bearer id.

`ue_pdu_session_modification`
Trigger a PDU Session Modification Request.
Message definition:

`ue_id` Integer. Identifier of UE.

`cid` Optional integer. Unique connection ID of the PDU session allocated during `pdn_connect` procedure (value is set to 0 for the initial PDU session establishment during the registration procedure).

`apn` Optional string. Access point name. Not required if `cid` is present.

`qos_rules`
Optional array. List of the QoS rules other than the default one. Each element of the array contains the followings objects:

`id` QoS rule identifier. Set it to 0 when creating a new QoS rule, or to the assigned value when modifying an existing QoS rule.

`qfi` Integer. Range: 0 to 63. QoS flow identifier.

`filters` Array of packet filters. See [TFT], page 80.

`qos_flow` Optional array. List of the QoS flow parameters including the default one. Each element of the array contains the followings objects:

`qfi` Integer. Range: 0 to 63. QoS flow identifier.

`5qi` Integer. Range: 1 to 254. 5QI of the QoS flow.

`gbr` Optional object. See [GBR], page 80.

`ue_assistance_information`
Trigger the sending of a UE assistance information message.
Message definition:

`ue_id` Integer. Identifier of UE.

`power_pref_indication`
Optional enumeration (normal, lowPowerConsumption). Defines the power preference indication to be sent in the UE assistance information message. LTE UE only.

`preferred_rrc_state`
Optional enumeration (idle, inactive, connected, outOfConnected). Defines the preferred RRC state to be sent in the UE assistance information message. NR UE only.

`preferred_max_cc`
Optional integer. Range: 1 to 31. Defines the reducedMaxCCs value for DL and UL to be sent in the UE assistance information message. NR UE only.

`preferred_max_layers`
Optional integer. Range: 1 to 4. Defines the reducedMaxMIMO_Layers for DL and UL to be sent in th UE assistance information message. NR UE only.

8.7 Remote events

Some messages (events) may be sent by LTEUE without client sollicitation.
To receive them, you need to register to those events via [remote event registration], page 69.
The received JSON will have a `message` property with the events name.

Ex:
Register to `<event name>` event:

```
{
  message: "register",
  register: "<event name>"
}
```

Message received:

```
{
  message: "<event name>",
  ...
}
```

Here is the list of events generated by LTEUE:

`ue_update`

Generated by a UE NAS or RRC state change:

- `ue_id` Integer. UE ID.

`measurement_report`

Generated when a UE sends a measurement report:

- `ue_id` Integer. UE ID.
- `meas_id` Integer. Measurement identifier.
- `report_type` String. Measurement report type. Can be `periodical_strongest_cells`, `cgi`, `event_a1`, `event_a2`, `event_a3`, `event_a4`, `event_a5`, `event_a6`, `event_b1_nr`, `event_b2_nr`, `event_b1`, or `event_b2`

`sms` Generated by SMS reception:

- `imsi` String. IMSI.
- `originator` String. SMS originator.
- `text` String. SMS text.
- `binary` String. If `text` is not set, base64 encoded string of SMS data.
- `dcs` Integer. Data coding scheme.

`sms_status_report`

Generated by the reception of SMS-STATUS_REPORT:

- `imsi` String. IMSI.
- `tp_qualifier` Enumeration: "SMS-SUBMIT", "SMS-COMMAND". TP-Status-Report-Qualifier as defined in 23.040 9.2.2.3 SMS-STATUS-REPORT type.

`tp_message_ref`
Integer. TP-Message-Reference as defined in 23.040 9.2.2.3 SMS-STATUS-REPORT type.

`tp_recipient_address`
String. TP-Recipient-Address as defined in 23.040 9.2.2.3 SMS-STATUS-REPORT type.

`tp_discharge_time`
String. TP-Discharge-Time as defined in 23.040 9.2.2.3 SMS-STATUS-REPORT type.

`tp_status`
Integer. TP-Status as defined in 23.040 9.2.2.3 SMS-STATUS-REPORT type.

`non_ip_data`
Generated by data reception over a non IP PDN or unstructured PDU session.

`ue_id` Integer. Identifier of UE.

`erab_id` Integer. ERAB identity of the non IP default bearer.

`data` String. ASCII representation of the data hexadecimal dump.

`pws_msg` Generated by reception of a PWS message (either CMAS or ETWS secondary message).

`ue_id` Integer. Identifier of UE.

`message_id`
Integer. Message Identifier, as per 3GPP TS 23.041

`serial_number`
Integer. Serial Number, as per 3GPP TS 23.041.

`message` Array of strings containing the UTF8 representation of each page of the message.

`srs` Generated for each SRS decoding, [Signal events], page 85,

`pdsch` Generated for each PDSCH decoding, [Signal events], page 85,

`npdsch` Generated for each NPDSCH decoding, [Signal events], page 85,

8.8 Signal events

Generated each time such a channel is decoded by the physical layer. This message is in binary format and includes a JSON structure and signal data as followed:
First 4 bytes are an 32 bit integer representing the length in bytes of the serialized JSON, followed by the serialized JSON itself.
Next 4 bytes are the length of the signal data in bytes followed by the data itself.
Note that the message can include several signal data. In this case, the pattern length/signal is repeated.

JSON data represent the associated log ([JSON log], page 66) and has following additional properties:

`label` String. Can be `rs` or `re`

`binary` Boolean. Always true

Signal data bytes are defined this way:

- Bytes 0...3: integer representing data length in bytes of the subsequent information.
- Bytes 4...7: integer representing data element size where:
  - 0: 32 bits floats
  - 1: 16 bits integer.
- Bytes 8..11: number of elements in data
- Remaining bytes are for data.

Note that <data length> = <# of elements> * <element size in bytes> + 8

For more information about signal data, please check `signals.js` code inside `ltewww` software package.

8.9 IP simulation messages

8.9.1 Common message definition

`name` String. Simulation name.

`ue_id` Integer. UE identifier.

`end_time` Float. End time.

`dst_addr` Optional string. `<address>[:<port>]` address and optionally port number of the remote test server.
If not set, use sim_ip_remote_addr of LTEUE configuration.
At least one of this two address must be set.
Must be an IP address or a MAC address if `type` is `ethernet` (`cbr_recv` and `cbr_send` cases).

`cid` Optional integer. Conenction ID. If defined, IP simulation will use the corresponding PDN to send and receive packets.

`apn` Optional string. Access point name. If defined, IP simulation will use the corresponding PDN to send and receive packets. It is ignored if `cid` is present.

8.9.2 Common response definition

`info` String. Human readable simulation result.

8.9.3 Definitions

`ping` Performs a ICMP ping.
Message definition:

`delay` Float. Delay in seconds between two ICMP echos.

`payload_len`
Integer. Size of ICMP payload (Between 4 and 1500).

`id` Optional integer. ICMP id. If not set, randomly defined.

Response definition:

`report`

`sent` Number of sent ECHO requests.

`recv` Number of received ECHO replies.

`cbr_send` Send UDP/Ethernet packets at constant bitrate.
Message definition:

- `type` Optional enumeration: udp, rtp voip or ethernet (default = udp). Select the packet format: UDP, RTP, VOIP (Voice Over IP) or Ethernet.
  VOIP uses RTP packets with 8 kHz timestamps and an optional silence compression (SID (Silence Indicator) payload size of 6 bytes and one SID packet).
- `bit_rate` Integer. Bitrate in bits per second.
- `payload_len`
  Integer. Size of UDP/RTP/Ethernet payload (Between 4 and 1500).

Additional parameter when type is `voip`:

- `vaf` Range: 0 to 100 (only for VOIP). Voice Activity Factor in percent. 100% means no silence.
- `mean_talking_duration`
  Float (only for VOIP). Mean talking duration in seconds.
- `sid_period`
  Optional integer. Silent duration in packets. If not set, period will be configured so that silent packets are sent at least every 160ms.

Additional parameter when type is `ethernet`:

- `ether_type`
  Optional integer (Between 0 and 65535). In case of Ethernet packets, sets the `ether_type` protocol number of the Ethernet header.

Response definition:

- `report`
  - `sent` Number of sent packets.
  - `recv` Number of received packets.

`cbr_recv` Receive UDP/Ethernet packets at constant bitrate.
Message definition:

- `type` Optional enumeration: udp, rtp voip ethernet (default = udp). Select the packet format: UDP, RTP, VOIP (Voice Over IP) or Ethernet.
  VOIP uses RTP packets with 8 kHz timestamps and an optional silence compression (SID (Silence Indicator) payload size of 6 bytes and one SID every 8 normal voice packets).
- `bit_rate` Integer. Bitrate in bits per second.
- `payload_len`
  Integer. Size of UDP/RTP/Ethernet payload (Between 4 and 1500).
- `vaf` Range: 0 to 100 (only for VOIP). Voice Activity Factor in percent. 100% means no silence.
- `mean_talking_duration`
  Float (only for VOIP). Mean talking duration in seconds.
- `start_delay`
  Optional float (default = 0). Tell the server to begin sending packets after `start_delay` seconds. It is useful to test paging.

`ether_type`
: Optional integer (Between 0 and 65535). In case of Ethernet packets, sets the `ether_type` protocol number of the Ethernet header.

Response definition:

`report`

`sent`	Number of sent packets.
`recv`	Number of received packets.

`tcp` Establish TCP connection(s) to send and/or receive data.
Message definition:

`connections`
: Optional integer (default = 1). Number of simultaneous connections.

`window_size`
: Optional integer. If set, forces TCP maximum window size

`notification_delay`
: Optional number (Default = 1). Interval in seconds between two notifications.

`direction`
: Optional string (default = `both`). Cabn be `tx` to only send packet, `rx` to only receive packets or `both` to send packets in both directions.

Notification definition:

`notification`
: String. Set to `progress`

`tx_size` Integer. Number of bytes sent since start of the simulation

`rx_size` Integer. Number of bytes sent since start of the simulation

`duration` Number. Duration is seconds since start of the simulation

Response definition:

`report`

`tx_size`	Integer. Number of bytes sent sinc start of the simulation
`rx_size`	Integer. Number of bytes sent sinc start of the simulation
`duration`	Number. Duration is seconds since start of the simulation
`info`	String. Human readable result

`flood_send`
: Send UDP packets by burst.
Message definition:

`payload_len`
: Integer. Size of UDP payload (Between 4 and 1500).

Response definition:

`report`

`sent`	Number of sent packets.
`recv`	Number of received packets.

`rate_kbps`
Transfer rate.

`flood_recv`
Receive UDP packets by burst.
Message definition:

`payload_len`
Integer. Size of UDP payload (Between 4 and 1500).

Response definition:

`report`

`sent` Number of sent packets.

`recv` Number of received packets.

`rate_kbps`
Transfer rate.

`http` Performs HTTP transfers in loop.
Message definition:

`url` String. URL to download.

`max_delay`
Float. Maximum delay between two connection attempts.

`max_cnx` Integer (default = 1000). Maximum number of connections.

Response definition:

`report`

`connections`
Number of transfer attempt.

`rx_size` Downloaded size in bytes.

`duration` Real transfer duration. Useful to estimate bitrate.

8.9.4 Start notification

When started, a notification message is sent.
This message is identified by a notification field set to string `start`.

8.10 IP simulation examples

1. Ping
   1. Client message
      ```
      {
          "message": "ping",
          "message_id": 42,
          "start_time": 1.5,
          "ue_id": 1,
          "delay": 1,
          "payload_len": 100
      }
      ```
   2. Server notification
      ```
      {
      ```

```
        "message": "ping",
        "message_id": 42,
        "notification": "start"
    }
```

3. Server response

```
    {
        "message": "ping"
        "message_id": 42,
        "sent": 100,
        "recv": 100,
        "info": "PING: sent 100, received 100"
    }
```

8.10.1 IP simulation server

Some IP simulations requires a server to communicate with.
PING test are handled direclty by network stacks implementing ICMP protocol.
A common HTTP server can be used for HTTP simulations.

In LTEUE package, you will find a `ltesim_server` program used for this communication.
It is mandatory for simulations like CBR and FLOOD.
In order to use this program, you need to copy the following files, available in your package, to your core network PC.

- ltesim_server
- libnopoll.so
- libcrypto.so.3 (See [openssl], page 5)
- libssl.so.3 (See [openssl], page 5)
- libnuma.so

Now, you can start this program in core network as below:

```
./ltesim_server -a <interface address>[:<port>]
```

Or, if you want HTTP handling:

```
./ltesim_server -a <interface address> -H <port>
```

For Ethernet, you need to select listening interface:

```
./ltesim_server -e <interface name>[/<ether_type>] -H <port>
```

8.11 Examples

1. Config
   1. Client sends

```
    {
        "message": "config_get",
        "message_id": "foo"
    }
```

   2. Server replies

```
    {
        "message_id": "foo",
        "message": "config_get",
        "name": "UE",
        "logs": {
```

```
        "phy": {
            "level": "error",
            "max_size": 0
        },
        ...
        "rrc": {
            "level": "debug",
            "max_size": 1
        }
    }
}
```

2. Error
   1. Client sends

      ```
      {
          "message": "bar",
          "message_id": "foo"
      }
      ```

   2. Server replies

      ```
      {
          "message_id": "foo",
          "message": "bar",
          "error": "Unknown message: bar"
      }
      ```

9 Command line monitor reference

The following commands are available:

`help` Display the help. Use `help` *`command`* to have a more detailed help about a command.

`t [ue|g|cpu|spl] [`*`period`*`]`
: Activate various traces on the console. The display is stopped when typing return. The default trace is `ue`. An optional display period (in seconds) is accepted.

Available traces:

`ue[:n]` UE MAC and PRACH traces. If `n` is provided, only display the UE ID `n`.

`g` Show global statistics.

`cpu` Display the CPU usage from the TRX (transceiver) API and the TX-RX latency statistics.

`spl` Display various statistics about the sent and received complex samples (at the TRX API level). For the TX side, the RMS and maximum sample value are displayed. The number of saturation events (`abs(sample) > 1`) are displayed too. For the RX side the RMS and maximum sample value are displayed. The unit is dB FS (dB Full Scale). 0 dB FS is reached with a square signal of amplitude 1.

`log [`*`log_options`*`]`
: Display the current log state. If *log_options* are given, change the log options. The syntax is the same as the `log_options` configuration property.

`tx_gain` *`gain`* `[`*`channel`*`]`
: Set the TX gain in dB of the radio driver. With an array of floats a different gain is specified for each channel. Same definition as the [tx_gain], page 23, property.

`rx_gain` *`gain`* `[`*`channel`*`]`
: Set the RX gain in dB of the radio driver. With an array of floats a different gain is specified for each channel. Same definition as the [rx_gain], page 23, property.

`rf_info` *`gain`*
: Get RF driver information.

`ue` List the configured UEs.

`pdn_connect [`*`ue_id`*`]` *`apn`*`|`*`emergency`* `[`*`auth username password`*`]`
: Send PDN connectivity / PDU session establishment request.

`pdn_disconnect [`*`ue_id`*`]` *`apn`*`|`*`emergency`*
: Send PDN disconnect / PDU session release request.

`rrc_reest [`*`ue_id`*`]`
: Trigger a RRC reestablishment.

`power_on [`*`ue_id`*`]`
: Initiate a UE power on.

`power_off [`*`ue_id`*`]`
: Initiate a UE power off.

`n3gpp_power_off [`*`ue_id`*`] [`*`n3gpp`*`]`
: Initiate a UE power off.

`deregister` [*ue_id*]
: Initiate a UE detach/deregistration.

`sms` *ue_id tel text* [*status_req*]
: Send SMS

`sms_command` *ue_id type msg_number dst*
: Send SMS-COMMAND.

`mbms_set` *ue_id* [*plmn.service_id*] [*plmn.service_id*]
: Starting receiving MBMS service(s).

`mbms` *ue_id*
: Show MBMS statistics.

`rlc_drop_rate` *UE_ID rb_id rate* [*is_srb*]
: Define a *rate* percentage of downlink RLC PDUs dropped.

`csfb` [*ue_id*] [*service_type*]
: Initiate a CS fallback.

`force_meas_report` [*ue_id*] *meas_id*
: Force a RRC Measurement Report message sending.

`tau_request` *ue_id*
: Trigger a NAS Tracking Area Update / mobility Registration Request procedure.

`cevent` *error|msg|<event>|help [error|msg]*
: Display event counters for errors, messages or a selected event. To get the list of error or message counters, you can type `cevent help error` or `cevent help msg`.

`com`
: COM connection status.

`cell_gain` *cell_index gain*
: Set the UL gain of the cell *cell_index*. The gain is in dB and must be <= 0. The gain of the other cells is not modified.
NR cell only.

10 Remote UE

When using tunnel interface with external program, you may want external program to be run on a different PC.
The Remote UE tool allows you to transfer IP traffic from each UE to a remote entity.

For this run `lterue` program on a different computer.
You don't need any specific license.
`lterue` uses GTP over SCTP to communicate with LTEUE.
`lterue` must be used with *tun_setup_script*.

Note that we recommend to use same version of `lterue` and `lteue`.

10.1 Configuration

`bind_addr`
: IP address and optional port on which the SCTP with connection to LTEUE is bound.

Note that *tun_setup_script* and *ext_app* prog member associated to UE will be forwarded to *lterue* and thus those scripts must be present in local directory.

For instance, if you put *lterue* on another PC, copy *lterue*, *config/rue.cfg*, *config/ue-if.cfg*, *config/ext_app.sh*, *libnopoll.so*, *libcrypto.so.1.1* and *libssl.so.1.1*.

11 UDC configuration reference

The UDC configuration is made by the script `udc-auto-cfg.sh`. For the input parameters See [cmd], page 24. The script needs to ouput on stdout the following lines:

- `LO_FREQ`: LO frequency confgured for the UDC devices belonging to the same `udc_port`
- `TX_POWER_OFFSET`: UDC up conversion gain [dB]. This quantity is used by the software to estimate the value of `ss-PBCH-BlockPower`
- `TX_POWER_MAXn`: it corresponds to the maximum power level [dBm] tolerated by the UDC IF port equally divided by the number of aggregated carriers using the same `udc_port`. `n` line output, one for each `rf_port`. This quantity is used by the software to find the maximum allowed `tx_gain` for each `rf_port` in order to avoid the UDC device IF port saturation.
- `IFn`: it corresponds to the intermediate frequency at which each SDR is configured. `n` line output, one for each `rf_port`.
- `TX_GAIN_MARGINn`: it corresponds to the `tx_gain` reduction [dB] from the maximum allowed value. It is automatically applied by the software by `rf_port` during the startup. `n` line output, one for each `rf_port`.

11.1 args Configuration

This section specifies how to configure the parameter `args` (See [args], page 24). The only mandatory string parameter is the UDC device enumeration, it specifies how the UDC has been mounted at Linux level. UDCB2 and UDCB4 are mounted as /dev/ttyUSBx and UDCA2 as /dev/ttyACMx. The other string parameters are optional, if not specified, they are configured with the default value. Supported parameters:

Clock configuration:

- A2: default(ingored). Any possibility to send clock configuration command for this UDC
- B2: internal,external,default(master=internal,slave=external). If only one UDC B2 in the setup default=internal.
- B4: internal,external,gps,default(internal)

TX port configuration:

- A2: 1,2,default(1). 1=port IF1, 2=port IF2
- B2: 1,2,3,4,default(2). 1=port IF1A, 2=port IF1B, 3=port IF2A, 4=port IF2B
- B4: 1,2,3,4,default(1,3). 1=port IF1, 2=port IF2, 3=port IF3, 4=port IF4

RX port configuration:

- A2: 1,2,default(2). 1=port IF1, 2=port IF2
- B2: 1,3,default(3). 1=port IF1A, 3=port IF2A
- B4: 1,2,3,4,default(2,4). 1=port IF1, 2=port IF2, 3=port IF3, 4=port IF4

Example: "/dev/ttyUSB0;clock=default;tx=default;rx=default"

11.2 Debug

To enable the `udc-auto-cfg.sh` debug logs it is required to enable the `trx` log level in debug mode in the configuration file. Example:

```
log_options: "all.level=error,all.max_size=0,nas.level=debug,nas.max_size=1,
s1ap.level=debug,s1ap.max_size=1,x2ap.level=debug,x2ap.max_size=1,
rrc.level=debug,rrc.max_size=1,trx.level=debug,trx.max_size=1",
```

12 Log file format

12.1 PHY layer

When a PHY message is dumped (debug level), the format is:

```
time layer dir ue_id cell rnti frame.subframe channel:short_content
        long_content
```

`time` Time using the selected format.

`layer` Layer (`[PHY]` here).

`dir` UL (uplink) or DL (downlink).

`ue_id` eNodeB UE identifier (hexadecimal, unique among all cells).

`cell` Cell index (hexadecimal).

`rnti` Associated RNTI (hexadecimal) or `-` if none.

`frame.subframe`
Frame number (0-1023) and either subframe number (0-9) for LTE and NB-IoT cells or slot number for NR cells.

`channel` PHY channel name (e.g. PUSCH, PUCCH, PRACH, SRS, PSS, PBCH, PDSCH, PHICH, PDCCH, EPDCCH, ...).

`short_content`
Single line content.

`long_content`
Hexadecimal dump of the message if `phy.max_size > 0`.

In the uplink messages, `epre` is the relative Energy per Resource Element in dB. The origin 0 dB corresponds to `tx_gain_offset` dBFS.

If UE power control is enabled, `p` is the absolute transmit power in dBm.

If the UE channel simulator is enabled, `p` is the absolute power before the channel simulation is applied. Moreover, if the UE channel simulator is enabled, `epre` is clamped to 0 dB to avoid a potential saturation in the RF interface.

12.2 MAC and RRC layers

When a message is dumped, the format is:

```
time layer - ue_id message
```

When a PDU is dumped (debug level), the format is:

```
time layer dir ue_id short_content
        long_content
```

`time` Time using the selected format

`layer` Layer (`[MAC]` or `[RRC]` here).

`dir` UL (uplink) or DL (downlink).

`ue_id` eNodeB UE identifier (hexadecimal, unique among all cells).

`cell_id` Primary cell index.

`short_content`
Single line content.

`long_content`

- MAC: hexadecimal dump of the message if `layer.max_size > 0`.
- RRC: full ASN.1 content of the RRC message if `layer.max_size > 0`.

`long_content`

- MAC, RLC, PDCP: hexadecimal dump of the message if `layer.max_size > 0`.
- RRC: full ASN.1 content of the RRC message if `layer.max_size > 0`.

12.3 RLC, PDCP and NAS layers

When a message is dumped, the format is:

```
time layer - ue_id message
```

When a PDU is dumped (debug level), the format is:

```
time layer dir ue_id short_content
        long_content
```

`time` Time using the selected format

`layer` Layer (`[RLC]`, `[PDCP]`, or `[NAS]` here).

`dir` UL (uplink) or DL (downlink).

`ue_id` eNodeB UE identifier (hexadecimal, unique among all cells).

`short_content`
Single line content.

- RLC, PDCP: preceded by the SRB or DRB identifier.

`long_content`

- NAS: full content of the NAS message if `layer.max_size > 0`.

12.4 IP layer

When a IP data PDU is dumped (debug level), the format is:

```
time layer dir short_content
        long_content
```

`time` Time using the selected format

`layer` Indicate the layer (`[IP]` here).

`dir` UL (uplink) or DL (downlink).

`short_content`
Single line content (at least the IP protocol and the source and destination address).

`long_content`
Optional hexadecimal dump of the PDU if `ip.max_size > 0`.

13 Known limitations

We present here the known limitations of LTEUE:

- No cell search (except for the initial connection).
- Handover is supported both in LTE and NR in UE simulation mode (`multi_ue:true`) between the configured cells. The real UE mode does not yet support handover.
- In UE simulation mode (`multi_ue:true`), events A1 to A6 and periodical report for strongest cells are supported for the configured cells. Events B1 and B2 are supported for EN-DC. RRC measurements are not yet supported in real UE mode.
- Subband periodic CQI is not supported (but wideband CQI and aperiodic CQI are supported).
- Category M1 specific:
  - Only CE-Mode A is supported.
  - No message repetition for PRACH.
  - No frequency hopping.
- NB-IoT specific:
  - Channel simulator is not supported.
- NR specific:
  - A single code block group is supported.
  - Semi-static HARQ ACK is not fully supported.
  - k1 (PDSCH to ACK delay in slots) must be larger than or equal to `rx_to_tx_latency`.
  - k2 (DCI to PUSCH delay in slots) must be larger than or equal to `rx_to_tx_latency`.
  - The RAR to PUSCH delay in slots must be larger than or equal to `rx_to_tx_latency + 1`.

14 Change history

14.1 Version 2025-12-12

- OpenSSL library is upgraded to 3.5.4
- removed deprecated DES-CBC IKE and IPsec encryption algorithm
- improved satellite propagation algorithm for NTN
- added LTE bands 111, 112, 113 and 252 definition
- added NR bands 68, 87, 88, 110 and 252 definition
- added the `auto` as default option for the `ntn_internal_model` parameter
- added the `feeder_mode` and `feeder_delay` parameters for the channel simulator in `satellite` mode
- added logicalChannelSR-Mask support in LTE and NR
- added logicalChannelSR-Prohibit support in LTE and NB-IoT
- added logicalChannelSR-DelayTimer support in NR
- added event D1 measurement report support in NR
- added conditional handover support in NR
- added `cp_dl` parameter for split 7.2
- added the `static`, `tdld30`, `ntn_tdla100` and `ntn_tdlc5` channel models to the channel simulator
- added `tcp` IP simulation
- added 16 bits float support for TRX driver

14.2 Version 2025-09-19

- updated NR RRC ASN.1 to release 18.6.0
- added `nr_need_for_gaps` parameter
- added `bwp_switching_delay` parameter
- added MIB dump to RRC logs
- added NAS coarse location reporting support for NB-IoT NTN scenario
- Multiple NB-IoT cells are now supported
- added `rf_port` parameter for RF port sharing among NB-IoT cells
- added ORAN 7.2 support for LTE cells
- added `gen_prb0` parameter

14.3 Version 2025-06-13

- updated RRC ASN.1 to release 18.5.0
- updated NR RRC ASN.1 to release 18.5.1
- updated LPP ASN.1 to release 18.4.0
- added coarse location reporting
- added NB-IoT R14 servingCellMeasInfo support
- added non 3GPP (ePDG and N3IWF) support
  - added `n3gpp` parameter
- added access point name to `tun_setup_script` arguments

- added `cid` to `pdn_connect`, `pdn_disconnect`, `ue_pdu_session_modification`, `ue_get` remote APIs and IP simulation messages
- added `ntn_internal_model` parameter at cell level
- added `min_distance`, `max_distance` and `bounce` parameters
- added remote API for `lterue`
- added `cell_sync` parameter for NR cell group configuration

14.4 Version 2025-03-14

- updated NR RRC ASN.1 to release 18.4.0
- added NR DL MIMO 8x8
- added NR FR2 NTN
- the crc=KO log is renamed to crc=FAIL
- added direct SCell activation support
- added R18 NR PDCP SN gap report support
- added `tx_gain_offset` at cell level
- added `cell_gain` monitor command

14.5 Version 2024-12-13

- updated RRC ASN.1 to release 18.3.0
- updated NR RRC ASN.1 to release 18.3.0
- added R18 3MHz cell bandwidth support for NR cells
- added NR band 106 definition
- added R14 skip uplink TX dynamic and SPS support
- `redcap` parameter is changed from a boolean to an enum. Boolean is still supported for backward compatibility
- added `eredcap_reduced_bb_bw` parameter
- added `pdsch_fer` parameter
- added `dl_ca` parameter
- added `max_mimo_layers_dl`, `nr_max_mimo_layers_dl` and `nr_max_mimo_layers_ul` parameters
- added `measurement_report` remote API event
- added `vrb_lib_path` parameter to the NR UE configuration for Intel vRANBoost support

14.6 Version 2024-09-13

- added LTE bands 107 and 108 definition
- added split 7.2 multi cell support
- added support for NR Paging Early Indication (PEI)
- added `status_req` to `sms` remote API and monitor command
- added `sms_status_report` event
- added `sms_command` remote API and monitor command
- added `license` remote API
- added `attenuation` parameter to all antenna types in the channel simulator
- added `tun_ifname` parameter

- added ue_del_all remote API
- added value 100_enhanced to f_raster parameter
- com_logs_lock parameter is renamed to com_log_lock. com_logs_lock is still supported for backward compatibility
- added com_log_us parameter
- added sid_period to cbr_send remote API
- added eab parameter

14.7 Version 2024-06-14

- OpenSSL library is upgraded to 1.1.1w
- added FR2 support
- added NR band 54 definition
- added data inactivity monitoring
- added apply_ul_mbr parameter
- added delay_sim parameter
- added ca_intraband parameter
- added access_control_classes and uac_access_identities parameters
- added satellite antenna type for NTN channel simulator
- added sim_path_loss to ue_get remote API
- added rrc_sel_resel parameter

14.8 Version 2024-03-15

- updated NR RRC ASN.1 to release 17.6.0
- added LTE bands 106, 253 and 254 definition
- added NR bands 31, 72, 105, 109 and 254 definition
- added IPv4 Link MTU request in PCO and automatic configuration of TUN interface based on the value received from the network
- added NR 2-steps RA SDT support
- added NR multi-CSI-PUCCH support
- added NR R17 PUSCH repetition support
- added qos_flows and erabs parameters to ue_get remote API
- added apply_ta_commands parameter
- added rlc_drop_rate remote API
- added cells.counters to config_get remote API
- added support of '+' in sms_centre_address
- added uplink_tx_switch_option parameter
- ntn_ground_position and ground_position_at_origin are deprecated, replaced by a single ground_position parameter
- added sprt_support parameter
- increased drx_cycle value range for NB-IoT UEs
- added handover_command, handover_success and handover_failure cevent counters
- added cfo parameter to stats remote API
- use trx_get_numa_nodes2 TRX API instead of trx_get_numa_nodes

14.9 Version 2023-12-15

- added EPS user plane integrity support when as_release is set to 17 or higher
- added RRC cell selection and reselection
- added NAS PLMN selection
- added support of TRX multi-thread API
- added extended measurement identities and measurement objects support
- added CSG support
- ca_filter_bc_3x101 parameter replaces the old ca_filter_bc_36101 and can now apply to NR UEs
- ul_ca parameter can also apply to NR UEs
- added loop_count and loop_delay to remote API messages
- added sim_events_loop_count and sim_events_loop_delay
- added plmnwact, oplmnwact, hplmnact, ehplmn and lrplmnsi used by the NAS PLMN selection procedure
- added ntn parameter to custom_freq_band object
- removed ntn parameter from the cell configuration object (the NTN info comes from the band used)
- added ue_usage_setting and voice_domain_preference_eutran parameters
- added Ethernet traffic generation type to cbr_recv and cbr_send
- added preferred_max_cc and preferred_max_layers parameters to ue_assistance_information API for NR UEs
- altitude parameter in ground_position_at_origin and ntn_ground_position parameters is now optional
- added ntn_service_dl_freq and ntn_service_ul_freq parameters for NR NTN cell groups
- added csg_info_list parameter
- added com_ssl_ca parameter for SSL verification
- added emergency_attach and imei_attach parameters
- added emergency parameter to pdn_connect and pdn_disconnect remote APIs
- mnc_nb_digits parameter is now also applicable to LTE and NB-IoT UEs

14.10 Version 2023-09-08

- updated EUTRA band combinations based on 3GPP TS 36.101 v18.2.0
- added the ptrs_density_recommendation_dl parameter
- snssai parameter is added to pdn_disconnect remote API
- sms_centre_address parameter is added
- NUMA configuration automatically uses RF frontend driver information
- attach_pdn_type parameter value ethernet is added
- pdn_type parameter value ethernet is added
- wus_support, wus_edrx_min_time_offset and gwus_paging_probability parameters are added for Cat-M1 UEs
- redcap and half_duplex parameters added for NR UEs
- supi_concealment_by_sim parameter is removed

14.11 Version 2023-06-10

- added LTE band 73 definition
- ntn, ntn_n_ta_ue and ntn_ground_position parameters have been moved to the cell configuration and are now available for NB-IoT and NR cells
- added ntn_eci_aligned_ecef parameter
- phy related logging parameters are moved in the phy layer object of config_set/config_get remote APIs
- added rrc.cell_meas=[0|1] log level
- fading is now applied to the PRACH signal when using the channel simulator
- attach_pdn_type parameter value non-ip is renamed to unstructured. non-ip is still supported for backward compatibility
- pdn_type parameter value non-ip in pdn_connect remote API is renamed to unstructured. non-ip is still supported for backward compatibility
- com_logs_lock parameter added to disable logs configuration change via remote API
- attach_pdn_ims parameter is added
- ims parameter is added to pdn_connect remote API
- ground_position_at_origin parameter is added
- lpp_support parameter is added

14.12 Version 2023-03-17

- com_addr parameter now uses [::] address instead of 0.0.0.0 in the delivered configuration files to allow IPv6 connection
- updated RRC ASN.1 to release 17.3.0
- updated NR RRC ASN.1 to release 17.3.0
- added LTE category 1bis support
- added inter-RAT EUTRA/NR support
- added EUTRA/NR CGI reporting support
- added LTE bands 54, 255 and 256 definition
- added NR bands 100, 101, 102, 104, 255 and 256 definition
- added wus_support, wus_edrx_min_time_offset and gwus_paging_probability parameters for NB-IoT UEs
- added rms_dbm parameter to stats remote API
- added cpu_core_list parameter to cell group
- added missing deregister monitor command in documentation
- t3412 parameter can be used for MICO requested T3512
- added eutra_voice_support and nr_voice_support parameters
- cfo parameter was wrongly named freq_shift in ue_get remote API documentation
- f_raster parameter supports the value 15_30_100
- delta_gscn parameter supports the value 7
- added snssai_credentials parameter
- increased sim_reader_index parameter range

14.13 Version 2022-12-16

- updated RRC ASN.1 to release 17.2.0
- updated NR RRC ASN.1 to release 17.2.0
- added Configured Grant Type1 support
- added eDRX support for NR UEs
- added enhanced skip uplink TX support for NR UEs
- added `ca_certificate` parameter to `eap_tls`
- added `snpn_access_mode` and `allowed_snpn` parameters
- added `cag_info_list` parameters
- added `tun_script_param` for tun mode
- `nr_support` parameter is renamed to `en_dc_support`. `nr_support` is still supported for backward compatibility
- added `ntn`, `ntn_n_ta_ue`, `ntn_ground_position` in NB-IoT UEs for Rel17 NTN support
- added `random_ap_subband_cqi` and `random_ap_subband_pmi` parameters
- added `inactive` value to `rrc_state` parameter in `ue_get` remote API
- added `utc` parameter to remote API response messages

14.14 Version 2022-09-16

- updated RRC ASN.1 to release 17.1.0
- updated NR RRC ASN.1 to release 17.1.0
- added NUMA architecture support
- added log support for remote UE. GTP-U and IP layers available
- added `freq_shift` and `sample_rate_offset` parameters to `ue_get` remote API
- added `gtp_socket_size` option for remote UE
- added `nr_forced_li` parameter
- added `ue_assistance_information` remote API
- added R17 35MHz and 45MHz cell bandwidth support for NR cells
- added `cross_pol_medium` and `cross_pol_high` MIMO correlation matrixes to channel simulator
- added `deregister` remote API
- added band 103 support
- added support for CRI_RI_LI_PMI_CQI report quantity
- added Cat-M R14 PDSCH scheduling enhancement, HARQ ACK bundling and 10 HARQ processes support
- added `dump_stdout` and `dump_stderr` parameters to `ext_app`

14.15 Version 2022-06-17

- OpenSSL library is upgraded to 1.1.1n
- improved global NR performances
- added `ipv4_local_addr`, `ipv6_remote_addr_prefix` and `ipv6_local_addr_prefix` TFT components
- `pdcch_decode_opt` and `pdcch_decode_opt_threshold` are now supported with NR
- the `delay_spread` channel simulator parameter is added for the new `tdla`, `tdlb`, `tdlc`, `tdld` and `tdle` channel types

- added start_timestamp and end_timestamp to log_get API
- added phy.rep=1 log level for NPUSCH/NPDSCH allocations and repetitions in each subframe
- added support for R16 NR RLC extended t-PollRetransmit and extended t-StatusProhibit
- added support for R16 NR PDCP extended discardTimer

14.16 Version 2022-03-18

- prach_delay is now available for NR UEs too
- added notes about channel reciprocity and SRS antenna switching
- updated NR UE capabilities reporting
- the NR UE configuration files found in config folder are changed to use a cell SCS of 15kHz in FDD to match the changes done in the gNB configuation files
- added channel estimation signal log for PDSCH (LTE, NR)
- supi_concealment_by_sim parameter is added

14.17 Version 2021-12-17

- a new phy.cell_meas log level is added
- license monitor command is added
- support of antenna panels in the multi-UE channel simulator is added
- rx_agc and rx_agc_timeout remote APIs are removed; use rx_gain instead
- ssf5120 and sf10240 DRX long cycle in RRC connected state is supported
- PDCCH order PRACH in LTE, NB-IoT and NR is supported
- aperiodic SRS is supported in NR
- NB-IoT NPRACH Format 2 is supported
- mbms_set remote API is added

14.18 Version 2021-09-17

- the minimum GLIBC version is now 2.17
- logs can be displayed with microseconds precision
- nas_5gs parameter is added for EUTRA/5GC in LTE, Category M1 and NB-IoT
- addition of control plane CIoT 5GS optimization
- sul_support parameter is added for NR supplementary uplink
- cpu_core_list parameter is added to control the list of cores used for multi threading
- forced_pci parameter is added for LTE, Category M1 and NR UEs
- new parameters are added to the channel simulator for antenna panels
- f_raster parameter supports the value 15
- as_release parameter supports the value 16
- NAI can be configured instead of IMSI
- the ue-xwu script is updated
- PRACH repetitions in LTE-M are added

15 License

For more information on licensing, please refer to license.pdf file.