LTE and NR Core Network

Version: 2020-12-16

Table of Contents

1 Introduction

LTEMME is a LTE EPC (Evolved Packet Core) implementation. It has a built-in MME (Mobility Management Entity), SGW (Serving Gateway), PGW (Packet Data Network Gateway), PCRF (Policy and Charging Rule Function), HSS (Home Subscriber Server) and EIR (Equipment Identity Register). It can easily be used with the Amarisoft LTE eNodeB to build a highly configurable LTE test network.
Depending on your software license, it also includes a NR 5GC (5G Core Network). It has build-in AMF (Access and Mobility Management Function), AUSF (Authentication Server Function), SMF (Session Management Function), UPF (User Plane Function).

2 Features

2.1 EPC

- LTE release 15 compliant.
- Implements one EPC with built-in MME, SGW, PGW, PCRF, HSS and EIR.
- Supports several eNodeBs with standard S1 interface (S1AP and GTP-U protocols).
- NAS integrity check and encryption using the AES, Snow3G and ZUC algorithms. Ciphering support is now subject to export rules for your country.
- Support of USIM cards using the XOR, Milenage or TUAK authentication algorithm.
- Handling of UE procedures: attach, authentication, security configuration, detach, tracking area update, service access, radio bearer establishment, paging.
- Multi-PDN support and built-in dynamic ERAB setup for easy VoLTE/IMS testing.
- Transparent access to the IP network (no external Serving Gateway or PDN Gateway is necessary).
- Configurable access point name, IP range, DNS and E-RAB QoS.
- Support sending of Public Warning System messages (ETWS/CMAS).
- IPv6 support.
- Configurable logging system for all channels with built-in text decoders.
- Remote API using WebSocket.
- Command line monitor.
- PSM and eDRX support.
- Supports several IMS servers with Rx interface.
- Support of NB-IoT RAT and control plane CIoT optimization.
- Non-IP data delivery CIoT feature.
- Attach without PDN connectivity CIoT feature.
- User management via internal database without any external HSS.
- Support of optional S6a interface with external HSS.
- Support of optional S13 interface with external EIR.
- Support of optional SGsAP interface with external VLR/MSC.
- Support of broadcast and multicast PDN options.
- Support of DCNR UEs.

2.2 5GC

- NR release 15 compliant.
- Implements one 5GC with built-in AMF, AUSF, SMF, UPF.
- Supports several gNodeBs with standard NG interface (NGAP and GTP-U protocols).
- NAS integrity check and encryption using the AES, Snow3G and ZUC algorithms. Ciphering support is now subject to export rules for your country.
- Support of USIM cards using the XOR, Milenage or TUAK 5G-AKA authentication algorithm.
- Handling of UE procedures: registration, authentication, security configuration, deregistration, service access, radio bearer establishment, paging.
- Multi PDU sessions support and built-in dynamic QoS flow setup for easy VoNR/IMS testing.

- Transparent access to the IP network (no external UPF is necessary).
- Configurable access point name, IP range, DNS and QoS flows.
- IPv4, IPv4v6, IPv6 and unstructured PDUs support.
- Configurable logging system for all channels with built-in text decoders.
- Remote API using WebSocket.
- Command line monitor.
- Supports several IMS servers with Rx interface.
- User management via internal database without any external HSS.
- Support of broadcast and multicast PDU session options.
- Support sending of Public Warning System messages (ETWS/CMAS).
- Support of N12 interface with external AUSF.
- Support of N8 interface with external UDM.
- Support of N17 interface with external 5G-EIR.
- Support of N50 interface with external CBC.
- Support of network slicing.

3 Requirements

3.1 Hardware requirements

- LTEMME can run on the same PC as the Amarisoft eNodeB/gNodeB if a simple and compact solution is needed. Otherwise, any reasonnably recent PC with at least one Gigabit Ethernet port is acceptable.
- A test USIM card should be plugged into the UE. Test USIM cards from Anritsu are supported by the default configuration. Other test USIM cards should work as well provided they implement the dummy XOR authentication algorithm and that their IMSI and secret key are known. USIM cards using the Milenage or TUAK algorithm are also supported.

3.2 Software requirements

- A 64 bit Linux distribution. Fedora 30 is the officially supported distribution.
  The following distributions are known as compatible:
  - Fedora 17 to 30
  - Cent OS 7
  - Ubuntu 12 to 18

4 Installation

[Quick installation instructions are also given in the Amarisoft eNodeB/gNodeB documentation in case LTEMME is installed on the same PC as the eNodeB/gNodeB].

The network access thru the Gigabit Ethernet port must be correctly configured.

LTEMME can be run directly from the directory when it was unpacked. No need for explicit installation.

4.1 Local network configuration

LTEMME will set up a new virtual network interface `tun0` where each UE has a specific IP address. If you want them to connect to your local network (and Internet), you need to set up IP forwarding and masquerading.

An example is found in the `lte_init.sh`:
Syntax:

```
sudo ./lte_init.sh [-6] <ifname>

sudo ./lte_init.sh default
sudo ./lte_init.sh -6 eth1
```

4.2 Linux setup

4.2.1 Packages

LTEMME 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
  ```

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

4.2.2 OpenSSL

LTEMME has been compiled against openssl version 1.1.1f.
If your system does not have compatible version installed you may have this error message at startup:

```
error while loading shared libraries: libssl.so.1.1: cannot open shared object file: No such file or directory
```

To overcome this problem, you may:

- Copy libssl.so.1.1 and libcrypto.so.1.1 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 at our support side at `support.amarisoft.com` with the information provided by below commands executed in LTEMME directory:

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

4.2.3 NGHTTP2

LTEMME has been compiled against nghttp2 version 1.41.0.
If your system does not have compatible version installed you may have this error message at startup:

```
error while loading shared libraries: libnghttp2.so.14: cannot open shared object file
```

To overcome this problem, you may:

- Copy nghttp2.so.14 from `libs` subdirectory of your release tarball.
  If you have installed software with automatic install script, this should have been done automatically.
- Install libnghttp2 with your package manager
- Compile and install proper nghttp2 version yourself

In case of persisting issue, raise a ticket at our support side at `support.amarisoft.com` with the information provided by below commands executed in LTEMME directory:

```
uname -a
ls -l
ldd ./ltemme
```

4.3 License key installation

LTEMME 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 LTEMME:

  ```
  ./ltemme config/mme.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 `ltemme.key` license key file.
- Copy the `ltemme.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, `ltemme` should start normally.

4.4 Initial testing

- Edit the file `config/mme.cfg` to set the bind address of the GTP-U interface. Normally it is the address of the default Ethernet of the PC (you can see it with `ifconfig`). You can also set the address of the DNS (`dns_addr` property). You don't need to change the other parameters for an initial test.
- LTEMME creates one virtual network interface where the UE traffic is redirected. A modification of the default routing rules and iptables is usually needed if you want to redirect the UE traffic to the local network and Internet. The script `lte_init.sh` in the Amarisoft LTEMME package gives an example of setup to configure a NAT to access the Internet.
- Start the program as root with:

  ```
  ./ltemme config/mme.cfg
  ```

  [The root access is only needed to set up the Linux virtual interface.]
- The command line interface is used to monitor the operation of LTEMME and to change the logging options. Use `help` to get the list of commands and `quit` to stop the program.

- Use `enb` to list the connected eNodeBs and `gnb` to list the connected gNodeBs.
- In addition to using the log file, you can monitor the traffic between LTEMME and the eNodeBs or gNodeBs with Wireshark. The LTE specific traffic is filtered by putting `s1ap || gtp` in the `filter` input area. The NR specific traffic is filtered by putting `ngap || gtp` in the `filter` input area.
- For optimal performance, it is better to avoid fragmenting the GTP-U packets. So the Ethernet interfaces used between the eNodeBs or gNodeBs and LTEMME should be configured to have a MTU of at least 1564 (assuming the UEs use the standard MTU of 1500). You can verify with Wireshark whether the GTP-U packets are fragmented.

5 Configuration reference

5.1 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.
6. Properties can be duplicated.
   Merge will be done by recursively overriding values considering reading direction.

```
{
    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.

The System Information Blocks use the ASN.1 GSER syntax defined in RFC 3641 (Generic String Encoding Rules for ASN.1 Types). The description of the exact content of the System Information Blocks can be found in 3GPP TS 36.331 (RRC).

5.2 Properties

`log_filename`
: String. Set the log filename. If no leading `/`, it is relative to the configuration file path. See [Log file format], page 70.

`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, RRC and PCDP layers).
- time=[sec|short|full]. Display the time as seconds, time only or full date and time (default = time only).
- file=cut. Close current file log and open a new one.
- file.rotate=now. Rename current log with timestamp and open new one.
- file.rotate=*size*. Rename current log every time it reaches *size* bytes open new one. Size is an integer and can be followed by K, M or G.
- file.path=*path*. When log rotation is enabled, 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: `nas`, `ip`, `s1ap`, `ngap`, `gtpu`, `rx`, `s6`, `cx`, `s13`, `sgsap`, `sbcap`, `n12`, `n8`, `n17`, , `n50`

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

`gtp_addr`

String. Set the IP address (and an optional port) on which the GTP-U packets are received. The default port is 2152. It is normally the IP address of the network interface connected to the core network.

Syntax:

- `"1.2.3.4"` (use default port)
- `"1.2.3.4:5678"` (use explicit port)
- `"2001:db8:0:85a3::ac1f:8001"` (IPv6 address and default port)
- `"[2001:db8:0:85a3::ac1f:8001]:5678"` (IPv6 address and explicit port)

`gtp_ext_addr`

Optional string. Set the IP address on which the eNodeB should transmit the GTP-U packets. It is the same as gtp_addr by default. It can be different if LTEMME is behind a NAT.

`gtp_payload_mtu`

Optional integer (range 68 to 16384, default = 1500). MTU in bytes for the GTP-U payload. Do not forget to update the network interface MTU accordingly for optimal performance. See [Initial testing], page 6.

`s1ap_bind_addr`

Optional string. IP address and optional port on which the S1AP SCTP connection is bound.

`ngap_bind_addr`

Optional string. IP address and optional port on which the NGAP SCTP connection is bound.

`plmn` String. PLMN identity of the MME (5 or 6 digits). It should match one of the PLMN identities broadcasted by the eNodeB or gNodeB.

`mme_group_id`
: Optional integer, range: 0 to 65535. Set the MME group ID.

`mme_code` Optional integer, range: 0 to 255. Set the MME code.

`amf_region_id`
: Optional integer, range: 0 to 255. Set the AMF region ID. If not present, the value is derived from the `mme_group_id` value. If present, it must match the value derived from the `mme_group_id` value if it is present, using the rules defined in 3GPP 23.003 chapter 2.10.2.2.2.

`amf_set_id`
: Optional integer, range: 0 to 1023. Set the AMF Set ID. If not present, the value is derived from the `mme_group_id` and `mme_code` values. If present, it must match the value derived from the and `mme_code` values if they are present, using the rules defined in 3GPP 23.003 chapter 2.10.2.2.2.

`amf_pointer`
: Optional integer, range: 0 to 63. Set the AMF Pointer. If not present, the value is derived from the `mme_code` value. If present, it must match the value derived from the `mme_code` value if it is present, using the rules defined in 3GPP 23.003 chapter 2.10.2.2.2.

`amf_name` Optional string. AMF name used for NGAP signalling. Default is set to amarisoft.amf.5gc.mnc<MNC>.mcc<MCC>.3gppnetwork.org.

`eps_5gs_interworking`
: Optional enumeration: none, without_n26, with_n26 (default = none). Defines whether inter RAT mobility between EPS and 5GS is supported or not, and whether N26 interface is supported or not.

`eplmn_list`
: Optional array of strings (1 to 15). List of equivalent PLMNs.

`relative_capacity`
: Optional integer. Range: 0 to 255. Default : 50. Set the MME or AMF relative capacity value used for MME or AMF load balancing in S1AP S1 Setup Response, S1AP MME Configuration Update, NGAP NG Setup Response and NGAP AMF Configuration Update messages.

`nas_cipher_algo_pref`
: Array of integers. Set the preferred algorithms for NAS encryption in decreasing order of preference. If none match the UE capabilities, then EEA0/5G-EA0 (no encryption) is selected.

  List of supported algorithms:

  `1` EEA1/5G-EA1 (Snow 3G)

  `2` EEA2/5G-EA2 (128 bit AES)

  `3` EEA3/5G-EA3 (ZUC)

  If encryption is necessary, for best performance use AES (EEA2/5G-EA2) as first choice if your CPU supports the AES NI Intel instruction set (available starting from Sandy bridge CPUs). Otherwise use Snow3G (EEA1/5G-EA1) or ZUC (EEA3/5G-EA3).
  Note that ciphering is subject to export rules depending on your country.

`nas_integ_algo_pref`
: Array of integers. Set the preferred algorithms for NAS integrity check in decreasing order of preference. If none match the UE capabilities, then EIA0/5G-IA0 (no integrity check) is selected.

  List of supported algorithms:

  `1` EIA1/5G-IA1 (Snow 3G)

  `2` EIA2/5G-IA2 (128 bit AES)

  `3` EIA3/5G-IA3 (ZUC)

  For best performance, use AES (EIA2/5G-IA2) as first choice if your CPU supports the AES NI Intel instruction set (available starting from Sandy bridge CPUs). Otherwise use Snow3G (EIA1/5G-IA1) or ZUC (EIA3/5G-IA3).

`tun_setup_script`
: String. Set the path of the shell script to set up the virtual network interface. Script is called for each PDN connectivity or PDU session with following parameters:

  1. Interface name
  2. PDN or PDU session index
  3. Access Point Name
  4. IP version: 'ipv4' or 'ipv6'
  5. IP address: first IP address for ipv4 and link local address for IPv6
  6. First IP address
  7. Last IP address

  If no script is given, no virtual network interface is created.

  Note: when using several PDNs or PDU sessions, they all share the same virtual network interface. So the IP configuration of this interface must be compatible with the IP address ranges of the PDNs or PDU sessions.
  Take a look at *config/mme-ifup* file as an example.

`t3402` Optional integer (default = -1). Value in seconds of the T3402 or T3502 timer. -1 means that the timer value is not transmitted in attach accept or TAU or registration accept so that the UE uses the default value (12 minutes).

`t3412` Optional integer (default = 1800). Value in seconds of the T3412 (TAU update) timer. -1 means that the timer is deactivated. This is the value sent to the UE in NAS signalling, unless the UE is requesting the use of a longer timeout with T3412 extended value information element.

`t3412_low_priority`
: Optional integer (default = t3412 value). Value in seconds of the T3412 (TAU update) timer if the UE indicates NAS signalling low priority. -1 means that the timer is deactivated. This is the value sent to the UE in NAS signalling, unless the UE is requesting the use of a longer timeout with T3412 extended value information element.

`t3512` Optional integer (default = 1800). Value in seconds of the T3512 (periodic registration) timer. -1 means that the timer is deactivated. This is the value sent to the UE in NAS signalling.

`psm` Optional boolean (default = true). If set to false, MME will ignore the PSM request sent by the UE.

`t3412_extended_forced`
: Optional integer (default = -1). Value in seconds of the T3412 extended timer if UE uses PSM. If different from -1, the MME will ignore the value requested by the UE and will send this one instead.

`force_t3412_extended_ie`
: Optional boolean (default = false). If set to false, the MME selects the greatest T3412 value between the one configured in the MME and the one requested by the UE for PSM (unless `t3412_extended_forced` is set), and it does not send the T3412 extended IE if the value can be encoded as a GPRS timer IE. If set to true, the MME accepts a T3412 value requested by the UE smaller than the configured one, and the T3412 extended IE is always sent.

`t3324_forced`
: Optional integer (default = -1). Value in seconds of the T3324 timer if UE uses PSM. If different from -1, the MME will ignore the value requested by the UE and will send this one instead.

`t3346` Optional integer (default = -1). Value in seconds of the T3346 timer. The timer is transmitted in the reject messages if the EMM or 5GMM cause is #22 (congestion) and the value is not -1.

`t3448` Optional integer (default = -1). Value in seconds of the T3448 timer. The timer is transmitted if the value is different from -1 and the UE indicates its support in the UE network capability information element.

`t3460` Optional integer (default = 6). Value in seconds of the T3460 or T3560 timer.

`t3460_wb_s1_ce`
: Optional integer (default = 24). Value in seconds of the T3460 timer for UE operating in WB-S1/CE mode.

`5gmm_backoff_timer`
: Optional integer. Value in seconds of the 5GMM DL NAS transport back-off timer. The timer is transmitted if the value is not -1.

`edrx` Optional boolean (default = true). If set to false, MME will ignore the eDRX request sent by the UE.

`edrx_ptw_wb_s1`
: Optional integer (0 to 15, default = 3). 4 bits Paging Time Window length for WB-S1 UEs as defined in 3GPP 24.008 chapter 10.5.5.32.

`edrx_ptw_nb_s1`
: Optional integer (0 to 15, default = 3). 4 bits Paging Time Window length for NB-S1 UEs as defined in 3GPP 24.008 chapter 10.5.5.32.

`edrx_cycle_forced`
: Optional integer (-1 to 15, default = -1). 4 bits E-UTRAN eDRX cycle length duration as defined in 3GPP 24.008 chapter 10.5.5.32. If different from -1, the MME will ignore the value requested by the UE and will send this one instead.

`ims_list` Optional array. Each entry is an object defining connection to Amarisoft IMS server. This is useful for SMS over SG or 3GPP mode of IMS server when Rx interface is not used.
Each entry has following members:

`ims_addr` IP address of Amarisoft IMS server.

`bind_addr`
IP address of network interface to use for IMS connection.

`ims_vops` Optional boolean (default = false). Set the IMS voice over PS session in S1 mode supported bit of the EPS network feature support field in the NAS attach accept message (VoLTE).
With NR, it also sets the IMS voice over PS session over 3GPP access indicator of the 5GS network feature support IE of the NAS registration access message.

`emc_bs` Optional boolean (default = false). Set the emergency bearer services in S1 mode supported bit of the EPS network feature support field in the NAS attach accept message (VoLTE, Release 9).

`emc` Optional integer (default = 0). Set the emergency service support indicator for 3GPP access bits of the 5GS network feature support IE in the NAS registration accept message. See 3GPP 24.501 table 9.11.3.5.1.

`emf` Optional integer (default = 0). Set the emergency service fallback indicator for 3GPP access bits of the 5GS network feature support IE in the NAS registration accept message. See 3GPP 24.501 table 9.11.3.5.1.

`epc_lcs` Optional boolean (default = false). Set the Location services indicator via EPC supported bit of the EPS network feature support field in the NAS attach accept message.

`5gs_sms_over_nas`
Optional boolean (default = true). Defines if 5GC should indicate the support of SMS over NAS in the 5GMM registration accept message, if the UE indicated its support in the 5GMM registration request message.

`emergency_number_list`
Optional array or objects. Defines a list of emergency numbers to be sent to the UE in the NAS Attach Accept, Tracking Area Update Accept or Registration Accept messages.
Each object must contain the following parameters:

`category` Integer. Bitmask of the category bits as defined in 3GPP TS 24.008 table 10.5.135d (bit 1: police, bit 2: ambulance, bit 3: fire brigade, bit 4: marine guard, bit 5: mountain rescue).

`digits` String. Emergency number.

`cp_ciot_opt`
Optional boolean (default = false). If true, enable control plane CIoT optimization (if supported by the UE).

`attach_without_pdn`
Optional boolean (default = false). If true, enable attach without PDN functionality (if supported by the UE).

`fifteen_bearers`
Optional boolean (default = false). If true, enable the use of 15 EPS radio bearers (if supported by the UE).

`network_name`
Optional string (default = empty). Set the network name in the EMM information or configuration update command message.

`network_short_name`
Optional string (default = empty). Set the network short name in the EMM information or configuration update command message.

`emm_information_time_enable`
: Optional boolean (default = true). Include the time and time zone in the EMM information or configuration update command message.

`emm_information_enable`
: Optional boolean. Default = true if `network_name` or `network_short_name` are not empty. If true, send the EMM information message after the NAS attach complete message or the configuration update command message after the registration accept message.

`attach_reject_error`
: Optional integer (default depending on scenario). Force value of EMM reject cause in NAS attach reject message.

`tracking_area_update_reject_error`
: Optional integer (default depending on scenario). Force value of EMM reject cause in NAS tracking area update reject message.

`service_reject_error`
: Optional integer (default depending on scenario). Force value of EMM reject cause in NAS service reject message.

`pdn_connect_reject_error`
: Optional integer (default depending on scenario). Force value of ESM reject cause in NAS PDN connectivity reject message.

`pdn_disconnect_reject_error`
: Optional integer (default depending on scenario). Force value of ESM reject cause in NAS PDN disconnect reject message.

`bearer_resource_allocation_reject_error`
: Optional integer (default depending on scenario). Force value of ESM reject cause in NAS bearer resource allocation reject message.

`bearer_resource_modification_reject_error`
: Optional integer (default depending on scenario). Force value of ESM reject cause in NAS bearer resource modification reject message.

`registration_initial_reject_error`
: Optional integer (default depending on scenario). Force value of 5GMM reject cause in NAS registration reject message (for 5GS registration type 1 or 4).

`registration_mobility_periodic_error`
: Optional integer (default depending on scenario). Force value of 5GMM reject cause in NAS registration reject message (for 5GS registration type 2 or 3).

`5gs_service_reject_error`
: Optional integer (default depending on scenario). Force value of 5GMM reject cause in NAS service reject message.

`pdu_session_establishment_reject_error`
: Optional integer (default depending on scenario). Force value of 5GSM reject cause in NAS PDU session establishment reject message.

`pdu_session_release_reject_error`
: Optional integer (default depending on scenario). Force value of 5GSM reject cause in NAS PDU session release reject message.

`pdu_session_modification_reject_error`
: Optional integer (default depending on scenario). Force value of 5GSM reject cause in NAS PDU session modification reject message.

`5gmm_dl_nas_transport_error`
: Optional integer (default depending on scenario). Force value of 5GMM reject cause in NAS DL NAS transport message.

`attach_result_mode`
: Optional string (default = auto). Set attach result of attach accept message.
Can be:

  `auto` This is standard LTE behavior.

  `eps_only` If set and UE is sending combined EPS/IMSI attach, the MME will answer with EPS only in attach accept message (EMM cause will be CS domain not available).

  `combined` If set and UE is sending EPS only attach, the MME will answer with combined in attach accept message.

`additional_update_result`
: Optional integer (default = 2). Set the value of additional update result in NAS attach accept message.
If set to -1, the additional update result won't be set.

`network_policy`
: Optional integer (range -1 to 15, default = -1). Set the value of the network policy information element described in 3GPP 24.301 chapter 9.9.3.52. The value -1 means that the IE is not transmitted.

`imeisv_request_in_smc`
: Optional boolean (default = true). Ask for the UE IMEISV in the NAS security mode command message. Must be enabled if `multi_sim` is set to `true`. IMEISV will always be requested if a S13 connection is defined, or if me_db object is defined.

`authentication_mode`
: Optional string (default = auto). Set NAS authentication procedure behavior.
Can be:

  `auto` The MME or AMF performs authentication procedure unless the UE is already successfully authentified.

  `force` The MME or AMF forces a new NAS authentication procedure even if the Attach Request or Registration Request was already successfully authentified

  `skip` The MME or AMF skips the NAS authentication procedure and uses EIA0/EEA0 or 5G-IA0/5G-EA0 algorithms. This needs to be supported on UE side also.

`skip_smc_proc`
: Optional boolean (default = false). If set to true, the MME or AMF will not perform a NAS security mode control procedure and will send all messages as plain. This needs to be supported on UE side also.

`force_guti_in_tau`
: Optional boolean (default = false). If set, GUTI IE will be systematically present in Tracking Area Update Accept message.

`attach_reject_filter`
: Optional object. Represent UE to reject when trying to attach.
Each property name represent IMSI. If set to `"*"`, every UE will be redirected using this filter.

Each property value is an integer defining the redirection type as described in *rrc_redirect* eNB configuration.

Example:

```
attach_reject_filter: {
    "*": 0,
    "0010112345678": 1
}
```

Will reject UE with IMSI *0010112345678* using redirection configuration 1 and all other UEs using redirection configuration 0.

`emm_procedure_filter`

Optional object. Allows to define the MME behavior for a list of EMM procedures. Each property name represents an EMM procedure. The ones currently supported are `attach`, `tracking_area_updating`, `detach`, `service_request`, `identity`, `authentication`, `security_mode_control` and `nas_transport`.
Each property value is an enum: `treat` (UE message is processed), `ignore` (UE message is ignored) or `reject` (UE message is rejected). By default all procedures are treated.

Example:

```
emm_procedure_filter: {
    attach: "treat",
    service_request: "reject"
}
```

`5gmm_procedure_filter`

Optional object. Allows to define the AMF behavior for a list of 5GMM procedures.
Each property name represents a 5GMM procedure. The ones currently supported are `registration_initial`, `registration_initial_with_security_protection`, `registration_mobility_periodic`, `service_request`, `identity`, `authentication`, `security_mode_control`, `generic_ue_update_command`, `nas_transport_n1_sm`, `nas_transport_sms` and `deregistration`.
Each property value is an enum: `treat` (UE message is processed), `ignore` (UE message is ignored) or `reject` (UE message is rejected). By default all procedures are treated.

Example:

```
5gmm_procedure_filter: {
    registration_initial: "treat",
    service_request: "reject"
}
```

`qci_dscp_mapping`

Optional array of objects. Allows to define a specific IP differentiated services code point for a given QCI/5QI. QCI/5QI not explicitly configured use the default DSCP value 0.
Each object must contain the following properties:

`qci` Integer (range 1 to 254). QCI or 5QI value.

`dscp` Integer (range 0 to 63). DSCP value.

`rate_bucket_duration`
: Optional. Range 500 to 5000 (default = 2000). Duration in ms for the average bit rate estimation. It is used to enforce the APN and Session Aggregate Maximum Bit Rate.

`nr_support`
: Optional boolean (default = false). Set it to true to enable Dual Connectivity with NR support.

`dcnr_implicit_support`
: Optional boolean (default = false). If set to true, the MME will not send the 2nd byte of the EPS network feature support IE because of DCNR. Can be useful to test the UE behavior.

`ecc_params`
: Optional object. Set the ECC network configuration for the SUPI protection and de-concealment of the SUCI. Applicable to 5GC only. It contains the following objects:

  `A`
  : Optional array of objects. Set the home network private key for profile A protection scheme.

    `home_nw_private_key`
    : String. Set the home network private key;

    `home_nw_key_id`
    : Optional integer in range 0 to 255 (default = 1). Set the home network key identifier.

  `B`
  : Optional array of objects. Set the home network private key for profile B protection scheme.

    `home_nw_private_key`
    : String. Set the home network private key;

    `home_nw_key_id`
    : Optional integer in range 0 to 255 (default = 2). Set the home network key identifier.

  Here is the procedure to generate a private/public key-pair:

```
Profile A:
openssl genpkey -algorithm x25519 -out key.pem
openssl pkey -in key.pem  -text

Profile B:
openssl ecparam -genkey -name secp256k1 -out key.pem
openssl ec -in key.pem  -noout -text -conv_form compressed
```

`nf_ssl_certificate`
: Optional string. Applicable to 5GC only. If set, forces SSL for NF interfaces. Defines CA certificate filename.

`nf_ssl_key`
: Optional string. Applicable to 5GC only. Mandatory if nf_ssl_certificate is set. Defines CA private key filename.

  Here is the procedure to generate the private key file key.pem and the certicate file cert.pem:

```
openssl req -new > cert.csr
```

```
openssl rsa -in privkey.pem -out key.pem
openssl x509 -in cert.csr -out cert.pem -req -signkey key.pem --days 365
```

`nssai` Applicable to 5GC only. Optional array. List of S-NSSAIs served by the AMF.
Default content is sst: 1 (eMBB).
Each entry will set a S-NSSAI value as defined below:

- `sst` Integer (range 1-255). Slice Service Type.
- `sd` Optional integer (range 0-0xFFFFFE). Slice Differentiator.

`default_nssai`
Applicable to 5GC only. Optional array. List of default S-NSSAIs served by the AMF.
Can only take S-NSSAIs contained in the non-default list above. If not present, takes the same content as the non-default list. See [nssai], page 19.

`com_addr` Optional string. Address of the WebSocket server remote API. See [Remote API], page 40.
If set, the WebSocket server for remote API will be enabled and bound to this address.
Default port is 9000.
Setting IP address to 0.0.0.0 will make remote API reachable through all network interfaces.

`com_name` Optional string. Sets server name. MME 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_auth` Optional object. If set, remote API access will require authentication.
Authentication meachanism is describe in [Remote API Startup], page 42, 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.

`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"
}
```

5.2.1 PDN options

Note that the options are also applicable to 5GS DNN.

`ignore_initial_apn`
Optional boolean (default = false). If false, UE will be rejected if its desired APN is unknown.

`pdn_list`
Array of objects. Configure the available EPS Packet Data Networks and 5GS Data Network Names. The first one is the one to which the UE accesses at the initial attach.

Each object contains the following properties:

`access_point_name`
String. Set the Access Point Name. Use dots (.) to separate the APN elements.
Array of string. You can use array to define aliases.

`pdn_type` Optional enumeration: ipv4, ipv6, ipv4v6, non-ip (default = ipv4). Select the PDN or PDU session type.

`first_ip_addr`
String. First available IPv4 address.

`last_ip_addr`
String. Last available IPv4 address.

`ipv4_auto_increment`
Optional boolean (default = false). If set to false, the same IPv4 address is allocated for successive activation / deactivation of the PDN or PDU session. If set to true, the IPv4 address is incremented for successive activation / deactivation of the PDN or PDU session.

`gateway` Optional string. If set, forces the address of the gateway used for this PDN or PDU session and sent to mme-ifup script. With default config, it will be used to provide a IP address to the tun interface.
If not set, the first IP of the subnet will be used.

`ip_addr_shift`
Optional integer (default = 0). The allocated IPv4 addresses are allocated starting from `first_ip_addr` with a difference of `2^ip_addr_shift`. Hence `last_ip_addr - first_ip_addr` must be a multiple of `2^ip_addr_shift`. This option can be useful in case of inter-UE communication to ensure that the IPv4 address of a given UE is the only one in its netmask.

`first_ipv6_prefix`
String. First available global IPv6 prefix used in Router Advertisement message sent to the UE (only the high 8 bytes of the IPv6 address are meaningful). Note that the selected prefix will also be used as the interface identifier sent in NAS signalling.

`last_ipv6_prefix`
String. Last available global IPv6 prefix used in Router Advertisement message sent to the UE (only the high 8 bytes of the IPv6 address are meaningful). Note that the selected prefix will also be used as the interface identifier sent in NAS signalling.

`ipv6_auto_increment`
Optional boolean (default = false). If set to false, the same IPv6 prefix is allocated for successive activation / deactivation of the PDN or PDU session. If set to true, the IPv6 prefix is incremented for successive activation / deactivation of the PDN or PDU session.

`ipv6_interface_identifier`
Optional string. Interface identifier for the MME network interface of this PDN or PDU session (only the low 8 bytes of the IPv6 address are meaningful).

`ipv6_interface_addr`
Optional string. IPv6 global address for the MME network interface of this PDN or PDU session. If not present, the address is `first_ipv6_prefix` with a ::0 interface identifier.

`ipv6_router_lifetime`
Optional integer (range 0 to 65535, default is 65535). IPv6 Router Advertisement router lifetime in seconds.

`ipv6_valid_lifetime`
Optional integer (default is infinity - 0xffffffff). IPv6 Router Advertisement valid lifetime in seconds.

`ipv6_pref_lifetime`
Optional integer (default is `ipv6_valid_lifetime` value). IPv6 Router Advertisement preferred lifetime in seconds.
Must not be greater than `ipv6_valid_lifetime`.

`ipv6_onlink_flag`
Optional boolean (default is true). Defines IPv6 Router Advertisement on-link flag state.

`ipv6_managed_addr_config_flag`
Optional boolean (default is false). Defines IPv6 Router Advertisement managed address configuration flag state.

`ipv6_other_config_flag`
Optional boolean (default is false). Defines IPv6 Router Advertisement other configuration flag state.

`ipv6_mtu` Optional integer (default is 0). Defines the MTU sent in the IPv6 Router Advertisement message. If set to 0, the MTU option is not sent.

`ipv6_ra_transmission_interval`
Optional integer (range -1 to 1800, default is 0). Time in seconds between 2 periodical multicast Router Advertisement transmission, once the initial 3 transmissions have been performed after opening the PDN or PDU session. The value -1 means that no multicast transmission is done at all (including the 3 initial ones). The value 0 means that periodical transmission is deactivated.

`ipv6_drop_rs`
: Optional boolean (default is false). Defines whether the incoming Router Solicitation messages should be dropped by the MME and UPF or not.

`ipv6_prefix_delegation_count`
: Optional integer (2, 4, 8, 16, 32). Defines the number of prefixes delegated by DHCPv6-PD (including the one allocated by the Router Advertisement message). Only the first IA_PD option in the DHCPv6 Solicit message is considered.

`dns_addr` String or array of strings. IPv4 or IPv6 addresses of the DNS servers.

`p_cscf_addr`
: Optional string or array of strings. IPv4 or IPv6 addresses of the P-CSCF servers (VoLTE).

`mtu_ipv4` Optional integer. Set MTU size (0 means disabled).

`mtu_non_ip`
: Optional integer. Set MTU size for non-IP PDN (0 means disabled, the minimum valid value is 128).

`mtu_unstructured_link`
: Optional integer. Set MTU size for unstructured PDU session (0 means disabled).

`ip_addr_config`
: Optional string. If set, this parameter defines the Access Point Name of a PDN or PDU session that will be used for IPv4 allocation. In such case, both PDNs or PDU sessions will share the same IPv4 range and thus, `first_ip_addr`, `last_ip_addr`, `ipv4_auto_increment`, `gateway`, `mtu_ipv4` and `ip_addr_shift` will be skipped.

`ipv6_prefix_config`
: Optional string. If set, this parameter defines the Access Point Name of a PDN or PDU session that will be used for IPv6 prefixes allocation. In such case, both PDNs or PDU sessions will share the same IPv6 prefix range and thus, `first_ipv6_prefix`, `last_ipv6_prefix`, `ipv6_auto_increment`, `ipv6_interface_identifier`, and `ipv6_prefix_delegation_count` will be skipped.

`operator` Optional array of objects. Each element defines an operator reserved container in protocol configuration.

Properties of each element:

`id` Integer. Container identifier, must be between 0xff00 and 0xffff as defined in TS 24.008.

`plmn` String. PLMN info of container.

`value` String. Value to send in hexadecimal string format.

`force` Optional boolean. If true, container will be sent event without request (false by default).

`authentication`
: Optional enumeration: `none`, `pap`, `chap` or `eap` (default set to `none`). Defines the authentication mechanism used for this APN.
`eap` is applicable to 5GC 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.

`apn_aggregate_max_bitrate_dl`
Optional integer (default = -1). EPS APN or 5GS PDU session aggregate maximum bitrate for downlink (in bits/s). If set to -1, no APN-AMBR or PDU session AMBR is configured and UE-AMBR is used instead.

`apn_aggregate_max_bitrate_ul`
Optional integer (default = -1). EPS APN or 5GS PDU session aggregate maximum bitrate for uplink (in bits/s). If set to -1, no APN-AMBR or PDU session AMBR is configured and UE-AMBR is used instead.

`emergency`
Optional boolean (default = false). If set, PDN will be selected for emergency calls.

`serving_plmn_rate_control`
Optional integer (range 0 to 65535, default = 0). Defines the serving PLMN rate control IE content when PDN is used with control plane CIoT optimization only. If the value configured is less than 10, the IE is not transmitted.

`apn_rate_control_params`
Optional object. If defined, and if the UE indicates APN rate control parameters support in its protocol configuration options, the following parameters will be sent in Core Network protocol configuration options:

`additional_exception_report`
Boolean. Indicates if exception reports are allowed once the limit is reached.

`ul_time_unit`
Enumeration: `unrestricted`, `minute`, `hour`, `day` or `week`.

`max_ul_rate`
Integer (range from 0 to 16777215). Number of messages allowed to be sent per `ul_time_unit`.

`additional_apn_rate_control_exception_data_params`
Optional object. If defined, and if the UE indicates additional APN rate control for exception data parameters support in its protocol configuration options, the following parameters will be sent in Core Network protocol configuration options:

`ul_time_unit`
Enumeration: `unrestricted`, `minute`, `hour`, `day` or `week`.

`max_ul_rate`
Integer (range from 0 to 65535). Number of messages allowed to be sent per `ul_time_unit`.

`backoff_timer`
Optional integer (default = -1). Value in seconds of the T3396/T3584/T3585 timers. The timer is transmitted in the ESM and 5GSM reject messages if the value is not -1.

`re_attempt_ind`
: Optional integer (range -1 to 255, default = -1). Value of octet 3 of the Re-attempt indicator information element, as specified in 3GPP TS 24.301 chapter 9.9.4.13A and 3GPP TS 24.501 chapter 9.11.4.17. The value -1 means that the information element is not sent.

`automatic_release`
: Optional boolean (default = false). If set, when the last associated dedicated EPS bearer is released the MME releases the default EPS bearer. With 5GS, when the last non default QoS flow is released, the SMF releases the PDU session.

`allow_multiple_pdn_connections`
: Optional boolean (default = false). If set, a UE can create multile PDN connections to this APN.

`ue_initiated_modification`
: Optional boolean (default = false). If set, the UE can request the modification of a bearer, otherwise the request is rejected.

`ip_src_violation_limit`
: Optional integer (default = -1). If greater than -1, the MME or UPF checks the IP source address of uplink packets. When `ip_src_violation_limit` packets are received, the PDN or PDU session is released. The value 0 means that the packets are dropped without triggering a release.

`tun_setup_script`
: Overrides [tun_setup_script], page 12, for this PDN or PDU session.

`tun_ifname`
: Optional string. If set, use this tun device instead of creating it.
Usefull when LTEMME has no root privileges.

`erabs`
: Array of objects. Each element defines an E-RAB (E-UTRAN Radio Access Bearer) associated to the PDN or a QoS flow associated to the PDU session. The first E-RAB or QoS flow is the default radio bearer and must always be present. The additional E-RABs and QoS flows are dedicated radio bearers and must include a Traffic Flow Template (TFT) unless they are defined as UE initiated.

  Property of each element:

  `qci`
  : Range: 1 to 255. QoS Class Identifier of the E-RAB or 5G QoS Identifier of the QOS flow.

  `priority_level`
  : Range: 1 to 15. Priority level.

  `pre_emption_capability`
  : Enumeration: `shall_not_trigger_pre_emption` or `may_trigger_pre_emption`.

  `pre_emption_vulnerability`
  : Enumeration: `not_pre_emptable` or `pre_emptable`.

  `setup_type`
  : Optional enumeration: automatic, on_demand, ue_initiated (default = automatic).

- If set to automatic, the dedicated bearer is created with the default bearer.
- If set to on_demand, the dedicated bearer is created when there is downlink traffic matching the TFT filters. This option is useful to automatically create a dedicated bearer for IMS RTP voice traffic.
- If set to ue_initiated, the dedicated bearer is created when receiving a ESM bearer resource allocation request message. In that case, the `gbr` object defines the maximum values allowed (MME will use the minimum between configured values and the ones sent by the UE) and `tft` object is not required (MME will use the filters sent by the UE).

`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. Required for dedicated bearers with `setup_type` different from ue_initiated. Each filter has the following properties:

`direction`
: Enumeration: `dl`, `ul` or `both`. Set the filter direction.

`id` Range: 0 to 14. Set the filter identifier.

`precedence`
: Range: 0 to 254. Set the filter precedence. All the filters must have different precedence. 0 is the highest precedence.

`components`
: Array of objects. Each component contains one of the following properties as described in 3GPP 23.060 chapter 15.3.2:

  `ipv4_remote_addr`
  : String. Match a remote (external network entity) IPv4 address with the additional `mask` property.

`ipv6_remote_addr`
: String. Match a remote (external network entity) IPv6 address with the additional `mask` property.

`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.

`on_demand_timeout`
: Optional integer. When `setup_type` is on_demand, set the duration (in ms) after which the dedicated bearer is released when there is no downlink or uplink traffic.

`on_demand_ul_trigger`
: Optional boolean (default = false). When `setup_type` is on_demand, if set to true an UL packet matching one of the TFT filters triggers the dedicated E-RAB or QoS flow establishment.

`transaction_identifier`
: Optional integer (range 0 to 127). If present, the transaction identifier IE is put in the EPS bearer activation message.

`llc_sapi`
: Optional integer (range 0 to 15). If present, the LLC service access point identifier IE is put in the EPS bearer activation message.

`radio_priority`
: Optional integer (range 0 to 7). If present, the radio priority IE is put in the EPS bearer activation message.

`packet_flow_identifier`
: Optional integer (range 0 to 127). If present, the packet flow identifier IE is put in the EPS bearer activation message.

`sm_qos`
: Optional string. If present, the quality of service IE is put in the EPS bearer activation message. The string must contain the hexadecimal representation of the IE without its IEI and length.

The following parameters are applicable to EPC only:

`esm_procedure_filter`
: Optional object. Allows to define the MME behavior for a list of ESM procedures.
Each property name represents an ESM procedure. The ones currently supported are `pdn_connectivity`, `pdn_disconnect`, `bearer_resource_allocation` and `bearer_resource_modification`.
Each property value is an enum: `treat` (UE message is processed), `ignore` (UE message is ignored) or `reject` (UE message is rejected).
By default all procedures are treated.

Example:

```
esm_procedure_filter: {
    pdn_connectivity: "treat",
    bearer_resource_allocation: "reject"
}
```

The following parameters are applicable to 5GC only:

`5gsm_procedure_filter`
: Optional object. Allows to define the SMF behavior for a list of 5GSM procedures.
Each property name represents a 5GSM procedure. The ones currently supported are `pdu_session_establishment`, `pdu_session_release` and `pdu_session_modification`.
Each property value is an enum: `treat` (UE message is processed), `ignore` (UE message is ignored) or `reject` (UE message is rejected).
By default all procedures are treated.

Example:

```
5gsm_procedure_filter: {
    pdu_session_establishment: "treat",
    pdu_session_modification: "reject"
}
```

`integrity_protection`
: Optional enumeration (disabled, preferred, required, default = disabled). Defines whether integrity should be used for the PDU session or not. If set to `preferred`, the 5GC will activate integrity protection based on the UE capabilities and the configured PDU session AMBR. If set to `required`, and if the UE does not support integrity protection for the bitrate configured in the PDU session AMBR, the request will be rejected with 5GSM error cause #82.

`confidentiality_protection`
: Optional enumeration (disabled, required, default = required). Defines if confidentiality must be used for the PDU session or not.

`apply_nas_transport_n1_sm_filter`
: Optional boolean (default = true). indicates whether the 5GMM procedure filter `nas_transport_n1_sm` should apply to this DNN or not.

`eps_5gs_interworking`
: Optional boolean (default = true). If set to true, interworking between EPS and 5GS is allowed for this APN/DNN. Otherwise it is forbidden.

`5gsm_congestion_re_attempt_ind`
: Optional integer (range -1 to 255, default = -1). Value of octet 3 of the Re-attempt indicator information element, as specified in 3GPP TS 24.501 chapter 9.11.4.21. The value -1 means that the information element is not sent.

`slices` Optional array. Defines the QoS flows by S-NSSAI.
If a supported S-NSSAI is not present in the array, the QoS flows defined in [erabs], page 24, applies.
Each entry will set specific QoS flows for a slice as defined below:

`snssai` S-NSSAI value.

`sst` Integer (range 1-255). Slice Service Type.

`sd` Optional integer (range 0-0xFFFFFE). Slice Differentiator.

`qos_flows`
: Array of QoS flows. Each element of the array has the same structure as an element in [erabs], page 24,
except that `"5qi"` shall be used instead of `"qci"`.

5.2.2 User database options

`ue_db`

Array of objects. Configure the user database. Each element is an entry for one user. The following properties are available:

`imsi` String. Set the IMSI.

`msisdn` Optional string. Set the MSISDN.

`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 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 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 35.231) is used.

`amf` Range: 0 to 65535. Set the Authentication Management Field.

`5gs_auth_type`
Applicable to 5GC only.
Optional enumeration: 5g_aka, eap_aka_prime (default = 5g_aka).
5GMM authentication method.

`at_result_ind`
Applicable to 5GC only.
Optional boolean (default = false).
Indicates if the AUSF shall include the AT_RESULT_IND attribute in message EAP-request/AKA'-Challenge.

`res_len` Optional integer (default = 8). Defines length of response in bytes during authentication. For TUAK authentication algorithm, the value must be 4, 8 or 16 bytes long.

`multi_sim`
Optional boolean (default = false). If true, allow several UEs to have the same IMSI (useful when using several identifical test SIM cards in different UEs at the same time). They are distinguished with their IMEI. Note: it is only allowed with the XOR authentication algorithm.

`isim_auth`
Optional object. If present, the object allows to configure some specific authentication parameters for the ISIM. Otherwise it uses the same parameters as those defined for the USIM. It contains the following configuration parameters: `sim_algo`, `K`, `op`, `opc`, `r`, `c`, `top`, `topc`, `keccak_iter` and `res_len`.

`ue_aggregate_max_bitrate_dl`
Optional integer (default = 3e9). UE aggregate maximum bitrate for downlink (in bits/s).

`ue_aggregate_max_bitrate_ul`
Optional integer (default = 1e9). UE aggregate maximum bitrate for uplink (in bits/s).

`t3412` Optional integer. Value in seconds of the T3412 (TAU update) ot T3512 timer for this IMSI. If not present, the MME or AMF will use the value coming from HSS or configured locally. It is sent to the UE in NAS signalling, unless the UE is requesting the use of a longer timeout with T3412 extended value information element.

`count` Optional integer (default = 1). Create `n` user entries by incrementing the IMSI and K.

`restrict_nr_as_2nd_rat`
Optional boolean (default = false). If set to true, the user is not allowed to use NR as secondary RAT (no DCNR).

`restrict_5gc_access`
Optional boolean (default = false). If set to true, the user is not allowed to access 5GC when coming from EPC (no handover or cell redirection).

`restrict_epc_access`
Optional boolean (default = false). If set to true, the user is not allowed to access EPC when coming from 5GC (no handover or cell redirection).

`restrict_pdn_list`
Optional boolean (default = false). If set to true, only the PDNs or PDU sessions listed in the `pdn_list` object are allowed for the user.

`pdn_list` Optional array. Each entry will set specific parameters for a PDN or PDU session as defined below:

`access_point_name`
String. Used to define what PDN or PDU session to configure.

`default` Optional boolean (default = false). If true and UE does not specify APN during Attach procedure or during the

first PDU session establishement procedure, this PDN or PDU session will be used.

`pdn_type` Optional enumeration: ipv4, ipv6, ipv4v6. Restrict the PDN type for this specific IMSI. The PDN or PDU session must be configured with a matching IP version.

`ipv4_addr`
Optional string. If set, the UE will always use this IPv4 address.

`ipv6_prefix`
Optional string. If set, the UE will always use this IPv6 prefix.

`imei` Optional string (14 or 15 digits). If set, this configuration only applies to UE with matching IMEI. Only supported for EPS, not 5GS.

`multicast`
Optional boolean (default = false). If set, IPv4 multicast traffic will be forwarded to this PDN or PDU session.

`broadcast`
Optional boolean (default = false). If set, IPv4 broadcast traffic will be forwarded to this PDN or PDU session.

`routes` Optional array. Each entry of array represent a list of filters. See [TFT components], page 25, for filters syntax except that remote refers to UE and local to network.
When a packet enters MME of UPF, if it matches one of the filter list, it will be sent to associated UE.

Ex:

```
routes: [
          [
            {
              ipv4_remote_addr: "10.0.0.0",
              mask: "255.255.255.0"
            }
          ]
        ]
```

Means that all packets addressed to 10.0.0.0/24 network will be sent to UE.

`nssai` Applicable to 5GC only.
Optional array. List of subscribed S-NSSAIs per DNN.
If not present, the list of the S-NSSAIs served by the AMF applies.
See [nssai], page 19.

`ue_db_filename`
Optional string. If present, store the current MME state in a persistent file. The MME state contains in particular the allocated TMSI, the associated security contexts and the allocated IP addresses.

5.2.3 Public Warning System (ETWS/CMAS) options

`pws_msgs`

Optional array of objects. Define a list of ETWS/CMAS messages which can be sent to the connected eNodeBs with the `pws_write` monitor command. Check TS 23.041 to have the exact definition of each field. Each message contains the following properties:

`local_identifier`
: Range: 0 to 65535. Local message identifier. Used as argument to the monitor commands `pws_write` or `pws_kill`.

`message_identifier`
: Range: 0 to 65535. Message Identifier.

`serial_number`
: Range: 0 to 65535. Serial Number.

`repetition_period`
: Optional integer, range: 0 to 4095 for LTE, 131071 for NR (default = 10). Periodicity of the warning message to be broadcast.

`number_of_broadcasts_requested`
: Optional integer, range: 0 to 65535 (default = 65535). Number of times a message is to be broadcast.

`warning_type`
: Optional integer. Range: 0 to 65535. Warning type (ETWS only).

`warning_security_info`
: Optional 50 byte hexadecimal string. Warning security information (ETWS optional).

`warning_message`
: Optional array of string. Message content (ETWS: optional, CMAS: mandatory). Each string is a message page and contains at most 93 GSM 7 bit or 41 UCS2 characters. At most 15 pages are allowed.

`warning_message_hex`
: Optional array of hexadecimal string. Message content (ETWS: optional, CMAS: mandatory). Each hexadecimal string is a message page and contains at most 164 characters. At most 15 pages are allowed. May be present only if `warning_message` is absent.

`data_coding_scheme`
: Optional integer. Range 0 to 255. Data coding scheme. Must be present if `warning_message_hex` is present. If `warning_message` is used, its default value is set to 0x0f for GSM 7 bit encoding and 0x48 for UCS2 encoding.

`concurrent_warning_message_ind`
: Optional boolean (default = false). Indicates that the warning message is a new message to be scheduled for concurrent broadcast with any other ongoing broadcast of warning messages.

`send_warning_indication`
: Optional boolean (default = false). SBCAP interface: Gives the presence of Send Write Replace Warning Indication IE in the SBCAP message WRITE-REPLACE WARNING REQUEST. N50 interface: Gives

the presence of sendRanResponse attribute the N50 message POST ../non-ue-n2-messages/transfer(N2InformationTransferReqData.

`warning_area_list`
Optional object. If present, the Warning Area List IE will be sent in the message WRITE-REPLACE WARNING REQUEST. It should contain one of the following objects:

`cell_id_list`
Optional array of objects (up to 65535). Each object must contain the following parameters:

`plmn` String (5 or 6 digits).

`cell_id` Integer. 28 bits long LTE cell identifier.

`tai_list` Optional array of objects (up to 65535). Each object must contain the following parameters:

`plmn` String (5 or 6 digits).

`tac` Integer. 2 bytes long tracking area code.

`emergency_area_id_list`
Optional array of integers (up to 65535). 3 bytes long emergency area identifier.

`warning_area_coordinates`
Optional hexadecimal string. Maximum length 1024 bytes. Warning Area Coordinates octet string (CMAS only).

`omc_id` Optional string. Maximum length 20 bytes. Identity of an Operation and Maintenance Centre.

`enb` Optional object. Global eNB ID to send in the message WRITE-REPLACE WARNING REQUEST.

`plmn` String (5 or 6 digits).

`enb_type` Optional string (macro, home, short_macro or long_macro). Default value is "macro". Type of the global eNB ID.

`enb_id` Integer. eNB ID.

`tai_list` Optional array of objects (up to 65535). TAI List to sent in the message WRITE-REPLACE WARNING REQUEST. Each object must contain the following parameters:

`plmn` String (5 or 6 digits).

`tac` Integer. 2 bytes long tracking area code.

`warning_area_list_5gs`
Optional object. 5GS Warning Area List to send in the message WRITE-REPLACE WARNING REQUEST. It should contain one of the following objects:

`nr_cell_id_list`
Optional array of objects (up to 65535). Each object must contain the following parameters:

`plmn` String (5 or 6 digits).

`cell_id` Integer. 36 bits long NR cell identifier.

`tai_list` Optional array of objects (up to 65535). Each object must contain the following parameters:

`plmn` String (5 or 6 digits).

`tac` Integer. 3 bytes long tracking area code.

`emergency_area_id_list`
Optional array of integers (up to 65535). 3 bytes long emergency area identifier.

`tai_list_5gs`
Optional array of objects (up to 65535). List of 5GS TAIs to send in the SBCAP message WRITE-REPLACE WARNING REQUEST or the N50 message POST ../non-ue-n2-messages/transfer(N2InformationTransferReqData). Each object must contain the following parameters:

`plmn` String (5 or 6 digits).

`tac` Integer. 3 bytes long tracking area code.

`ran_node_id`
Optional integer. Applicable to SBCAP interface only. Value of the global RAN node ID to send in the SBCAP message WRITE-REPLACE WARNING REQUEST. It should contain one of the following objects:

`gnb` gNB identifier.

`plmn` String (5 or 6 digits).

`gnb_id_bits`
Integer. Range 22 to 32. gNB ID length in bits.

`gnb_id` Integer. The gNB global identifier.

`ng_enb` ngENB identifier. See [enb], page 33.

`rat_selector_5gs`
Optional boolean. Default value is false. Applicable to SBCAP interface only. Indicates the presence of RAT Selector 5GS IE in the message WRITE-REPLACE WARNING REQUEST.

`n50_rat_selector`
Optional enumeration: nr, eutra, both. Default value is both. Applicable to N50 interface only. Gives the value of ratSelector attribute in N2InformationTransferReqDataTransfer.

`n50_ran_node_id_list`
Optional array of objects. Applicable to N50 interface only. See [ran_node_id], page 34. List of the global RAN node ID to send in the N50 message POST ../non-ue-n2-messages/transfer(N2InformationTransferReqData).

5.2.4 NAS special conformance testing options

The MME or AMF can automatically activate UE test mode during attachment and configure test loop mode A, B or G (see 3GPP 36.509 an 38.509 for details). Once the loop is closed, the user can transmit downlink IP packets to the UE that will be loopbacked in UL.

`nas_test_procedure`
Optional object allowing to configure the test procedure. It must contain the following objects:

`test_loop_mode`
: Enumeration: none, a, b, g. Defines which test loop will be activated.

`lb_setup_list`
: Optional array used for test loop mode A if UL PDCP SDU scaling is required. Each element of the array must contain the following 2 objects:

  `ul_pdcp_sdu_size`
  : Integer (range 0 to 1520). UL PDCP SDU size in bytes.

  `drb_id`
  : Integer (range 1 to 32). Data Radio Bearer identity on which the UL PDCP SDU scaling is applied.

`ip_pdu_delay`
: Integer (range 0 to 255). Transmission delay in seconds of the EUTRA UL PDCP SDUs or NR UL SDAP SDUs when operating in test loop mode B.

`operation_mode`
: Enumeration (`upper` or `rlc`). `upper` means that data is returned in uplink at the EMM entity. `rlc` means that data is returned in uplink at the RLC AM-SAP of SRB1bis for NB-IoT UE or at the RLC AM-SAP of SRB2 for E-UTRA UE. Used in test loop mode G.

`repetitions`
: Integer (0 to 127). Number of repetitions of received content of received user data in downlink in uplink. Used in test loop mode G.

`ul_data_delay`
: Integer (0 to 255). Uplink data delay in seconds. Used in test loop mode G.

5.2.5 Rx options

`rx`
: Optional object allowing to configure the Rx options. It can contain the following objects:

  `bind_addr`
  : Optional string. IP address and optional port on which the Rx SCTP connection is bound. The default address is the same as the S1AP SCTP connection and the default port is 3868.

  `qci`
  : Optional object. It can contain five integer properties: audio, video, application, data and control that defines the QCI to use.
  Default is 1 for audio, 2 for video and application, 6 for data and control.

  `origin_realm`
  : Optional string. Defines the string sent in the Origin-Realm AVP for Rx messages. Default is set to `mnc<MNC>.mcc<MCC>.3gppnetwork.org`.

  `origin_host`
  : Optional string. Defines the string sent in the Origin-Host AVP for Rx messages. Default is set to `epc.mnc<MNC>.mcc<MCC>.3gppnetwork.org`.

  `reservation_priority`
  : Optional array of 16 elements defining the S1AP ARP (Allocation and Retention Priority) parameters to be used for each Rx reservation prior-

ity level. If not present, `priority_level` is set to 15 (no priority), `pre_emption_capability` is set to `shall_not_trigger_pre_emption` and `pre_emption_vulnerability` is set to `not_pre_emptable`. If present the array must be ordered by increasing Rx priority level (from 0 to 15) and must contain the following fields:

`priority_level`
: Range: 1 to 15.

`pre_emption_capability`
: Enumeration: `shall_not_trigger_pre_emption` or `may_trigger_pre_emption`.

`pre_emption_vulnerability`
: Enumeration: `not_pre_emptable` or `pre_emptable`.

`emergency`
: Optional object defining the QCI and ARP parameters to be used for the emergency dedicated EPS bearer context. If not present, `qci` is set to 1, `priority_level` is set to 1 (highest priority), `pre_emption_capability` is set to `may_trigger_pre_emption` and `pre_emption_vulnerability` is set to `not_pre_emptable`.

`qci` Range: 1 to 255.

`priority_level`
: Range: 1 to 15.

`pre_emption_capability`
: Enumeration: `shall_not_trigger_pre_emption` or `may_trigger_pre_emption`.

`pre_emption_vulnerability`
: Enumeration: `not_pre_emptable` or `pre_emptable`.

5.2.6 S6a options

`s6`
: Optional object allowing to configure the S6a options. It can contain the following objects:

`server_addr`
: String. IP address and optional port of the HSS used for S6a interface. The default port is 3868.

`bind_addr`
: Optional string. IP address and optional port on which the S6a SCTP connection is bound. The default address is the same as the S1AP SCTP connection.

`origin_realm`
: Optional string. Defines the string sent in the Origin-Realm AVP for S6 messages. Default is set to `mnc<MNC>.mcc<MCC>.3gppnetwork.org`.

`origin_host`
: Optional string. Defines the string sent in the Origin-Host AVP for S6 messages. Default is set to `epc.mnc<MNC>.mcc<MCC>.3gppnetwork.org`.

`transaction_timeout`
: Optional integer (range 1 to 15000, default = 2000). Defines the timeout in milliseconds for a transaction with the HSS.

`watchdog_duration`
: Optional integer (range 0 to 36000000, default = 30000). Tw watchdog timer in milliseconds to send the Diameter Device Watchdog Request message. The value 0 deactives the watchdog.

5.2.7 EIR/S13 options

`me_db`
: Optional object allowing to define a list of IMEI (14 digits without the last Check Digit one) or IMEISV (16 digits), and their status (whitelisted, blacklisted, greylisted). If not present, all devices are considered as whitelisted.
It can contain the following objects:

  `default_status`
  : Enumeration (whitelisted, blacklisted, greylisted). Defines the default status for devices not explicitly defined in the next objects.

  `whitelist`
  : Optional array. It contains a list of IMEI or IMEISV whitelisted.

  `blacklist`
  : Optional array. It contains a list of IMEI or IMEISV blacklisted.

  `greylist` Optional array. It contains a list of IMEI or IMEISV greylisted.

  Example:

```
me_db: {
  default_status: "blacklisted",
  whitelist: [
    "01234567100000",
    "0123456700000001"
  ]
}
```

`s13`
: Optional object allowing to configure the S13 options. It can contain the following objects:

  `server_addr`
  : String. IP address and optional port of the EIR used for S13 interface. The default port is 3868.

  `bind_addr`
  : Optional string. IP address and optional port on which the S13 SCTP connection is bound. The default address is the same as the S1AP SCTP connection.

  `origin_realm`
  : Optional string. Defines the string sent in the Origin-Realm AVP for S13 messages. Default is set to `mnc<MNC>.mcc<MCC>.3gppnetwork.org`.

  `origin_host`
  : Optional string. Defines the string sent in the Origin-Host AVP for S13 messages. Default is set to `epc.mnc<MNC>.mcc<MCC>.3gppnetwork.org`.

`transaction_timeout`
: Optional integer (range 1 to 15000, default = 2000). Defines the timeout in milliseconds for a transaction with the EIR.

`watchdog_duration`
: Optional integer (range 0 to 36000000, default = 30000). Tw watchdog timer in milliseconds to send the Diameter Device Watchdog Request message. The value 0 deactives the watchdog.

5.2.8 SGs options

`sgs`

Optional object allowing to configure the SGs options. It can contain the following objects:

`csfb_allowed`
: Optional boolean (default = false). If set to true, Circuit Switched Fall back procedures are accepted, otherwise they are rejected.

`lac` Optional integer (default = 0x001). Defines the Location Area Identifier of the MSC/VLR to connect to.

`server_addr`
: String. IP address and optional port of the MSC/VLR used for SGs interface. The default port is 29118.

`bind_addr`
: Optional string. IP address and optional port on which the SGs SCTP connection is bound. The default address is the same as the S1AP SCTP connection.

5.2.9 SBc options

`sbcap_bind_addr`
: Optional string. IP address and optional port on which the SBc SCTP connection is bound. The default address is the same as the S1AP SCTP connection.

5.2.10 N12 options

`n12`

Optional object allowing to configure the N12 interface options. It can contain the following objects:

`api_root` Optional string. According to the definition in TS 29.501, api_root is in the form: <scheme>://<host>:<port>, where <scheme> is "http" or "https". This field shall be present if an external AUSF is used.

`transaction_timeout`
: Optional integer (range 1 to 15000, default = 4000). Defines the timeout in milliseconds for a transaction with the AUSF.

`bind_addr`
: Optional string. IP address and optional port on which the N12 TCP connection is bound. The default address is the same as the GTP-U connection.

5.2.11 N8 options

`n8`

Optional object allowing to configure the N8 interface options. It can contain the following objects:

`api_root` Optional string. According to the definition in TS 29.501, api_root is in the form: <scheme>://<host>:<port>, where <scheme> is "http" or "https". This field shall be present if an external UDM is used.

`transaction_timeout`
Optional integer (range 1 to 15000, default = 4000). Defines the timeout in milliseconds for a transaction with the UDM.

`bind_addr`
Optional string. IP address and optional port on which the N8 TCP connection is bound. The default address is the same as the GTP-U connection.

5.2.12 N17 options

`n17`

Optional object allowing to configure the N17 interface options. It can contain the following objects:

`api_root` Optional string. According to the definition in TS 29.501, api_root is in the form: <scheme>://<host>:<port>, where <scheme> is "http" or "https". This field shall be present if an external 5G-EIR is used.

`transaction_timeout`
Optional integer (range 1 to 15000, default = 4000). Defines the timeout in milliseconds for a transaction with the 5G-EIR.

`bind_addr`
Optional string. IP address and optional port on which the N17 TCP connection is bound. The default address is the same as the GTP-U connection.

5.2.13 N50 options

`n50`

Optional object allowing to configure the N50 interface options. It can contain the following objects:

`api_root` Optional string. According to the definition in TS 29.501, api_root is in the form: <scheme>://<host>:<port>, where <scheme> is "http" or "https". This field shall be present if an external 5G-EIR is used.

`transaction_timeout`
Optional integer (range 1 to 15000, default = 4000). Defines the timeout in milliseconds for a transaction with the CBC.

`bind_addr`
Optional string. IP address and optional port on which the N50 TCP connection is bound. The default address is the same as the GTP-U connection.

5.2.14 CP-EDT options

`cp_edt` Optional object allowing to configure CP-EDT options. It can contain the following objects:

- `mode` Optional enumeration: disabled, forced, automatic. Default value is automatic. If disabled is set: CP-EDT feature is disabled in the MME. If forced is set: CP-EDT is processed by the EMM whatever the NAS rai received with UL data. If automatic is set: if NAS rai indicates that downlink data is expected, CP-EDT is processed by the EMM. Otherwise connection establishment is requested by the MME.
- `max_dl_len_nb` Optional integer. Default value is 85. Largest DL packet data allowed without fallback to RRC connection establishment in NB-IoT.

6 Remote API

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

6.1 Messages

Messages exchanged between client and LTEMME 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 3 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 double. 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.

- Response

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

  `message` String. Same as request.

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

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

- Events

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

`message`	String. Event name.
`time`	Number representing time in seconds. Usefull to send command with absolute time.

6.2 Startup

When WebSocket connections is setup, LTEMME will send a first message with name and type of `PROG`.

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

```
{
    "message": "ready",
    "type": "MME",
    "name: <name>
}
```

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

```
{
    "message": "authenticate",
    "type": "MME",
    "name: <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": "MME",
    "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.

6.3 Errors

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

6.4 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 LTEMME.
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 127.0.0.1:9000 '{"message": "config_get"}'
```

6.5 Common messages

`config_get`

Retrieve current config.

Response definition:

`type` Always "MME"

`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 9,

`max_size` See [log_options], page 9,

`count` Number. Number of bufferizer logs.

`rotate` Optional number. Max log file size before rotation.

`path` Optional string. Log rotation path.

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

`cch` Boolean. True if CCH dump is enabled (UE only).

`signal` Boolean. True if PHY layer signal dump is enabled.

`config_set`

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

`logs` Object. Represent logs configuration. Same structure as config_get (See [config_get logs member], page 43).

All elements are optional.
Layer name can be set to `all` to set same configuration for all layers.

`relative_capacity`
: Optional integer. Range: 0 to 255. Default : 50. Set the MME or AMF relative capacity value used for MME or AMF load balancing in S1AP S1 Setup Response, MME Configuration Update, NGAP NG Setup Response and NGAP AMF Configuration Update messages.

`attach_reject_error`
: Optional integer (default depending on scenario). Force value of EMM reject cause in NAS attach reject message.

`tracking_area_update_reject_error`
: Optional integer (default depending on scenario). Force value of EMM reject cause in NAS tracking area update reject message.

`service_reject_error`
: Optional integer (default depending on scenario). Force value of EMM reject cause in NAS service reject message.

`pdn_connect_reject_error`
: Optional integer (default depending on scenario). Force value of ESM reject cause in NAS PDN connectivity reject message.

`pdn_disconnect_reject_error`
: Optional integer (default depending on scenario). Force value of ESM reject cause in NAS PDN disconnect reject message.

`bearer_resource_allocation_reject_error`
: Optional integer (default depending on scenario). Force value of ESM reject cause in NAS bearer resource allocation reject message.

`bearer_resource_modification_reject_error`
: Optional integer (default depending on scenario). Force value of ESM reject cause in NAS bearer resource modification reject message.

`registration_initial_reject_error`
: Optional integer (default depending on scenario). Force value of 5GMM reject cause in NAS registration reject message (for 5GS registration type 1 or 4).

`registration_mobility_periodic_error`
: Optional integer (default depending on scenario). Force value of 5GMM reject cause in NAS registration reject message (for 5GS registration type 2 or 3).

`5gs_service_reject_error`
: Optional integer (default depending on scenario). Force value of 5GMM reject cause in NAS service reject message.

`pdu_session_establishment_reject_error`
: Optional integer (default depending on scenario). Force value of 5GSM reject cause in NAS PDU session establishment reject message.

`pdu_session_release_reject_error`
: Optional integer (default depending on scenario). Force value of 5GSM reject cause in NAS PDU session release reject message.

`pdu_session_modification_reject_error`
: Optional integer (default depending on scenario). Force value of 5GSM reject cause in NAS PDU session modification reject message.

`5gmm_dl_nas_transport_error`
: Optional integer (default depending on scenario). Force value of 5GMM reject cause in NAS DL NAS transport message.

`attach_reject_filter`
: Optional Object. Represent UE to reject when trying to attach.
Each property name represent IMSI. If set tp `"*"`, every UE will be redirected using this filter.
Each property value may be:

  `null` Removes redirection matching IMSI

  `integer` Defines redirection type as described in *rrc_redirect* eNB configuration.

  `string` Defines PLMN to redirect to

`t3402` Optional integer. Value in seconds of the T3402 or T3502 timer. -1 means that the timer value is not transmitted in attach accept or TAU accept or registration accept so that the UE uses the default value (12 minutes).

`t3412` Optional integer. Value in seconds of the T3412 (TAU update) timer. -1 means that the timer is deactivated.

`t3412_low_priority`
: Optional integer. Value in seconds of the T3412 (TAU update) timer if the UE indicates NAS signalling low priority. -1 means that the timer is deactivated.

`t3512` Optional integer (default = 1800). Value in seconds of the T3512 (periodic registration) timer. -1 means that the timer is deactivated. This is the value sent to the UE in NAS signalling.

`psm` Option boolean (default = true). If set to false, MME will ignore the PSM request sent by the UE.

`t3412_extended_forced`
: Optional integer. Value in seconds of the T3412 extended timer if UE uses PSM. If different from -1, the MME will ignore the value requested by the UE and will send this one instead.

`force_t3412_extended_ie`
: Optional boolean (default = false). If set to false, the MME selects the greatest T3412 value between the one configured in the MME and the one requested by the UE for PSM (unless `t3412_extended_forced` is set), and it does not send the T3412 extended IE if the value can be encoded as a GPRS timer IE. If set to true, the MME accepts a T3412 value requested by the UE smaller than the configured one, and the T3412 extended IE is always sent.

`t3324_forced`
: Optional integer. Value in seconds of the T3324 timer if UE uses PSM. If different from -1, the MME will ignore the value requested by the UE and will send this one instead.

`t3346` Optional integer. Value in seconds of the T3346 timer. The timer is transmitted in the reject messages if the EMM of 5GSM cause is #22 (congestion) and the value is not -1.

`t3448` Optional integer (default = -1). Value in seconds of the T3448 timer. The timer is transmitted if the value is different from -1 and the UE indicates its support in the UE network capability information element.

`t3460` Optional integer (default = 6). Value in seconds of the T3460 or T3560 timer.

`t3460_wb_s1_ce`
Optional integer (default = 24). Value in seconds of the T3460 timer for UE operating in WB-S1/CE mode.

`5gmm_backoff_timer`
Optional integer. Value in seconds of the 5GMM DL NAS transport back-off timer. The timer is transmitted if the value is not -1.

`edrx` Option boolean (default = true). If set to false, MME will ignore the eDRX request sent by the UE.

`edrx_ptw_wb_s1`
Optional integer. 4 bits Paging Time Window length for WB-S1 UEs as defined in 3GPP 24.008 chapter 10.5.5.32.

`edrx_ptw_nb_s1`
Optional integer. 4 bits Paging Time Window length for NB-S1 UEs as defined in 3GPP 24.008 chapter 10.5.5.32.

`edrx_cycle_forced`
Optional integer. 4 bits E-UTRAN eDRX cycle length duration as defined in 3GPP 24.008 chapter 10.5.5.32. If different from -1, the MME will ignore the value requested by the UE and will send this one instead.

`ims_vops` Optional boolean. Set the IMS voice over PS session in S1 mode supported bit of the EPS network feature support field in the NAS attach accept message (VoLTE).
With NR, it also sets the IMS voice over PS session over 3GPP access indicator of the 5GS network feature support IE of the NAS registration access message.

`emc_bs` Optional boolean. Set the emergency bearer services in S1 mode supported bit of the EPS network feature support field in the NAS attach accept message (VoLTE, Release 9).

`emc` Optional integer. Set the emergency service support indicator for 3GPP access bits of the 5GS network feature support IE in the NAS registration accept message.

`emf` Optional integer. Set the emergency service fallback indicator for 3GPP access bits of the 5GS network feature support IE in the NAS registration accept message.

`epc_lcs` Optional boolean. Set the Location services indicator via EPC supported bit of the EPS network feature support field in the NAS attach accept message.

`5gs_sms_over_nas`
: Optional boolean (default = true). Defines if 5GC should indicate the support of SMS over NAS in the 5GMM registration accept message, if the UE indicated its support in the 5GMM registration request message.

`cp_ciot_opt`
: Optional boolean. If true, enable control plane CIoT optimization (if supported by the UE).

`attach_without_pdn`
: Optional boolean. If true, enable attach without PDN functionality (if supported by the UE).

`fifteen_bearers`
: Optional boolean (default = true). If true, enable the use of 15 EPS radio bearers (if supported by the UE).

`attach_result_mode`
: Optional string. Set attach result of attach accept message.
Can be:

  `auto` This is standard LTE behavior.

  `eps_only` If set and UE is sending combined EPS/IMSI attach, the MME will answer with EPS only in attach accept message (EMM cause will be CS domain not available).

  `combined` If set and UE is sending EPS only attach, the MME will answer with combined in attach accept message.

`additional_update_result`
: Optional integer. Set the value of additional update result in NAS attach accept message.
If set to -1, the additional update result won't be set.

`network_policy`
: Optional integer (range -1 to 15, default = -1). Set the value of the network policy information element described in 3GPP 24.301 chapter 9.9.3.52. The value -1 means that the IE is not transmitted.

`authentication_mode`
: Optional string (default = auto). Set NAS authentication procedure behavior.
Can be:

  `auto` The MME or AMF performs authentication procedure unless the UE is already successfully authentified.

  `force` The MME or AMF forces a new NAS authentication procedure even if the Attach Request or Registration Request was already successfully authentified

  `skip` The MME or AMF skips the NAS authentication procedure and uses EIA0/EEA0 or 5G-IA0/5G-EA0 algorithms. This needs to be supported on UE side also.

`skip_smc_proc`
: Optional boolean (default = false). If set to true, the MME or AMF will not perform a NAS security mode control procedure and will send all messages as plain. This needs to be supported on UE side also.

`force_guti_in_tau`
: Optional boolean (default = false). If set, GUTI IE will be systematically present in Tracking Area Update Accept message.

`emm_procedure_filter`
: Optional object. Allows to define the MME behavior for a list of EMM procedures.
Each property name represents an EMM procedure. The ones currently supported are `attach`, `tracking_area_updating`, `detach`, `service_request`, `identity`, `authentication`, `security_mode_control` and `nas_transport`.
Each property value is an enum `treat` (UE message is processed), `ignore` (UE message is ignored) or `reject` (UE message is rejected).
Example:

```
emm_procedure_filter: {
    attach: "treat",
    service_request: "reject"
}
```

`5gmm_procedure_filter`
: Optional object. Allows to define the AMF behavior for a list of 5GMM procedures.
Each property name represents a 5GMM procedure. The ones currently supported are `registration_initial`, `registration_mobility_periodic`, `service_request`, `identity`, `authentication`, `security_mode_control`, `generic_ue_update_command`, `nas_transport_n1_sm`, `nas_transport_sms` and `deregistration`.
Each property value is an enum: `treat` (UE message is processed), `ignore` (UE message is ignored) or `reject` (UE message is rejected).
Example:

```
5gmm_procedure_filter: {
    registration_initial: "treat",
    service_request: "reject"
}
```

`eplmn_list`
: Optional array of strings (0 to 15). List of equivalent PLMNs. Use an empty array to remove a previously set list.

`nr_support`
: Optional boolean (default = false). Set it to true to enable Dual Connectivity with NR support.

`dcnr_implicit_support`
: Optional boolean (default = false). If set to true, the MME will not send the 2nd byte of the EPS network feature support IE because of DCNR. Can be useful to test the UE behavior.

`ecc_params`
: Optional object. Set the ECC network configuration for the SUPI protection and de-concealment of the SUCI. Applicable to 5GC only. It contains the following objects:

  `A` Optional array of objects. Set the home network private key for profile A protection scheme.

`home_nw_private_key`
: String. Set the home network private key;

`home_nw_key_id`
: Optional integer in range 0 to 255 (default = 1). Set the home network key identifier.

`B`
: Optional array of objects. Set the home network private key for profile B protection scheme.

`home_nw_private_key`
: String. Set the home network private key;

`home_nw_key_id`
: Optional integer in range 0 to 255 (default = 2). Set the home network key identifier.

`pdn_list`
: Optional array of object. Each object can contain the following properties:

`apn`
: String. APN allowing to identify the PDN or PDU session to be modified.

`operator`
: Optional array of objects. Each element defines an operator reserved container in protocol configuration.

Properties of each element:

`id`
: Integer. Container identifier, must be between 0xff00 and 0xffff as defined in TS 24.008.

`plmn`
: String. PLMN info of container.

`value`
: String. Value to send in hexadecimal string format.

`force`
: Optional boolean. If true, container will be sent event without request (false by default).

`serving_plmn_rate_control`
: Optional integer (range 0 to 65535). Defines the serving PLMN rate control IE content when PDN is used with control plane CIoT optimization only. If the value configured is less than 10, the IE is not transmitted.

`apn_rate_control_params`
: Optional object. If defined, and if the UE indicates APN rate control parameters support in its protocol configuration options, the following parameters will be sent in Core Network protocol configuration options:

`additional_exception_report`
: Boolean. Indicates if exception reports are allowed once the limit is reached.

`ul_time_unit`
: Enumeration: `unrestricted`, `minute`, `hour`, `day` or `week`.

`max_ul_rate`
: Integer (range from 0 to 16777215). Number of messages allowed to be sent per `ul_time_unit`.

`additional_apn_rate_control_exception_data_params`
: Optional object. If defined, and if the UE indicates additional APN rate control for exception data parameters support in its protocol configuration options, the following parameters will be sent in Core Network protocol configuration options:

  `ul_time_unit`
  : Enumeration: `unrestricted`, `minute`, `hour`, `day` or `week`.

  `max_ul_rate`
  : Integer (range from 0 to 65535). Number of messages allowed to be sent per `ul_time_unit`.

`backoff_timer`
: Optional integer. Value in seconds of the T3396/T3584/T3585 timers. The timer is transmitted in the ESM and 5GSM reject messages if the value is not -1.

`re_attempt_ind`
: Optional integer (range -1 to 255, default = -1). Value of octet 3 of the Re-attempt indicator information element, as specified in 3GPP TS 24.301 chapter 9.9.4.13A and 3GPP TS 24.501 chapter 9.11.4.17. The value -1 means that the information element is not sent.

`ipv6_router_lifetime`
: Optional integer (range 0 to 65535). IPv6 Router Advertisement router lifetime in seconds.

`ipv6_valid_lifetime`
: Optional integer. IPv6 Router Advertisement valid lifetime in seconds.

`ipv6_pref_lifetime`
: Optional integer (default is `ipv6_valid_lifetime` value). IPv6 Router Advertisement preferred lifetime in seconds. Must not be greater than `ipv6_valid_lifetime`.

`ipv6_onlink_flag`
: Optional boolean. Defines IPv6 Router Advertisement onlink flag state.

`ipv6_managed_addr_config_flag`
: Optional boolean (default is false). Defines IPv6 Router Advertisement managed address configuration flag state.

`ipv6_other_config_flag`
: Optional boolean (default is false). Defines IPv6 Router Advertisement other configuration flag state.

`ipv6_mtu` Optional integer (default is 0). Defines the MTU sent in the IPv6 Router Advertisement message. If set to 0, the MTU option is not sent.

`ipv6_ra_transmission_interval`
: Optional integer (range -1 to 1800, default is 0). Time in seconds between 2 periodical multicast Router Advertisement transmission, once the initial 3 transmissions have been performed after opening the PDN or PDU session. The value -1 means that no multicast transmission is done at all (including the 3 initial ones). The value 0 means that periodical transmission is deactivated.

`ipv6_drop_rs`
: Optional boolean (default is false). Defines whether the incoming Router Solicitation messages should be dropped by the MME and UPF or not.

`automatic_release`
: Optional boolean (default = false). If set, when the last associated dedicated EPS bearer is released the MME releases the default EPS bearer. With 5GS, when the last non default QoS flow is released, the SMF releases the PDU session.

`allow_multiple_pdn_connections`
: Optional boolean (default = false). If set, a UE can create multile PDN connections to this APN.

`ue_initiated_modification`
: Optional boolean (default = false). If set, the UE can request the modification of a bearer, otherwise the request is rejected.

`ip_src_violation_limit`
: Optional integer (default = -1). If greater than -1, the MME or UPF checks the IP source address of uplink packets. When `ip_src_violation_limit` packets are received, the PDN or PDU session is released. The value 0 means that the packets are dropped without triggering a release.

`p_cscf_addr`
: Optional string or array of strings. IPv4 or IPv6 addresses of the P-CSCF servers (VoLTE). Use an empty array to remove any previously configured P-CSCF servers.

  The following parameters are applicable to EPC only:

  `esm_procedure_filter`
  : Optional object. Allows to define the MME behavior for a list of ESM procedures.
    Each property name represents an ESM procedure. The ones currently supported are `pdn_connectivity`, `pdn_disconnect`, `bearer_resource_allocation` and `bearer_resource_modification`.
    Each property value is an enum: `treat` (UE message is processed), `ignore` (UE message is ignored) or `reject` (UE message is rejected).

Example:

```
esm_procedure_filter: {
    pdn_connectivity: "treat",
    bearer_resource_allocation: "reject"
}
```

The following parameters are applicable to 5GC only:

`5gsm_procedure_filter`
: Optional object. Allows to define the SMF behavior for a list of 5GSM procedures.
Each property name represents a 5GSM procedure. The ones currently supported are `pdu_session_establishment`, `pdu_session_release` and `pdu_session_modification`.
Each property value is an enum: `treat` (UE message is processed), `ignore` (UE message is ignored) or `reject` (UE message is rejected).
By default all procedures are treated.

Example:

```
5gsm_procedure_filter: {
    pdu_session_establishment: "treat",
    pdu_session_modification: "reject"
}
```

`integrity_protection`
: Optional enumeration (disabled, preferred, required, default = disabled). Defines whether integrity should be used for the PDU session or not. If set to `preferred`, the 5GC will activate integrity protection based on the UE capabilities and the configured PDU session AMBR. If set to `required`, and if the UE does not support integrity protection for the bitrate configured in the PDU session AMBR, the request will be rejected with 5GSM error cause #82.

`confidentiality_protection`
: Optional enumeration (disabled, required, default = required). Defines if confidentiality must be used for the PDU session or not.

`apply_nas_transport_n1_sm_filter`
: Optional boolean (default = true). indicates whether the 5GMM procedure filter `nas_transport_n1_sm` should apply to this DNN or not.

`eps_5gs_interworking`
: Optional boolean (default = true). If set to true, interworking between EPS and 5GS is allowed for this APN/DNN. Otherwise it is forbidden.

`5gsm_congestion_re_attempt_ind`
: Optional integer (range -1 to 255, default = -1). Value of octet 3 of the Re-attempt indicator information element, as specified in 3GPP TS 24.501 chapter 9.11.4.21. The value -1 means that the information element is not sent.

`log_get` Get logs.
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.

`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 9. 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 9.

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

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. Depends on log time configuration (See [log_options], page 9):
If time is set to *short*, milliseconds since start of the day.
If time is set to *full*, milliseconds since January 1st 1970.
If time is set to *sec*, milliseconds since start of the LTEMME.

`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.

Note that only one request can be sent by client.
If a request is sent before previous one has returned, previous one will be sent without matchine min/max/timeout conditions.

`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.

`quit` Terminates ltemme.

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

`stats` Report statistics for LTEMME.
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.

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 LTEMME monitor.

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

`emm_registered_ue_count`
Integer. Number of UEs in EMM-REGISTERED or 5GMM-REGISTERED state.

`s1_connections`
Array of objects. List of S1AP connection betweens eNBs and MME. Each object contains the following fields:

`plmn` String. PLMN of the Global eNB ID.

`enb_id_type`
String (macro, home, short_macro or long_macro). Type of identifier of the Global eNB ID.

`enb_id` Integer. Identifier of the Global eNB ID.

`ip_addr` String. IP address and port of the eNB.

`ta_list` Array of objects. List of the Tracking Areas served by the eNB. Each object contains the following fields:

`plmn` String. PLMN of Tracking Area.

`tac` Integer. Tracking Area Code.

`emm_connected_ue_count`
Integer. Number of UEs in EMM-CONNECTED state for this S1AP connection.

`ng_connections`
Array of objects. List of NGAP connection betweens RANs and AMF. Each object contains the following fields:

`plmn` String. PLMN of the Global RAN ID.

`ran_id_type`
String (gNB, ng-eNB or N3IWF). Type of identifier of the Global RAN ID.

`ran_id` Integer. Identifier of the Global RAN ID.

`ip_addr` String. IP address and port of the RAN.

`ta_list` Array of objects. List of the Tracking Areas served by the RAN. Each object contains the following fields:

`plmn` String. PLMN of Tracking Area.

`tac` Integer. Tracking Area Code.

`cn_connected_ue_count`
Integer. Number of UEs in 5GMM-CONNECTED state for this NGAP connection.

`register` Register client to message generated by server. Message definition:

`register` String or array of string. List of message to register to.
Can be `non_ip_data`, `generic_nas_transport`, `5gs_nas_transport`, `eps_bearer_notification`, `qos_flow_notification`

`unregister`
: String or array of string. List of message to unregister.
Can be `non_ip_data`, `generic_nas_transport`, `5gs_nas_transport`, `eps_bearer_notification`, `qos_flow_notification`

6.6 LTE messages

`ue_get` Get UE informations.
Message definition:

`imsi` Optional string. If set, retrieve only information from UE with matching IMSI.

`imei` Optional string (14 or 15 digits). If set, retrieve only information from UE with matching IMEI.

`radio_capabilities`
: Optional boolean. If set, provides `radio_capabilities` in response.

Response definition:

`ue_list` Array of current UEs.
Each element has the following definition:

`imsi` String. IMSI.

`imeisv` String. IMEISV.

`m_tmsi` Optional string. M-TMSI. Present for LTE or NB-IoT UEs.

`5g_tmsi` Optional string. 5G-TMSI. Present for NR UEs.

`tac` Integer. Current tracking area code.

`tac_plmn` String. Current tracking area PLMN.

`ue_aggregate_max_bitrate_dl`
: Number. UE aggregate maximum bitrate for downlink.

`ue_aggregate_max_bitrate_ul`
: Number. UE aggregate maximum bitrate for uplink.

`registered`
: Boolean. True if UE is currently registered to network.

`t3412` Optional integer. T3412 timer in seconds. Only present if the LTE or NB-IoT UE is registered to network.

`t3324` Optional integer. T3324 timer in seconds. Only present if the LTE or NB-IoT UE is registered to network and PSM is activated.

`edrx` Optional object. eDRX configuration. Only present if the LTE or NB-IoT UE is registered to network and eDRX is activated. The object has the following definition:

`paging_time_window`
: Integer. 4 bits 4 bits Paging Time Window length as defined in 3GPP 24.008 chapter 10.5.5.32

`cycle` Integer. 4 bits E-UTRAN eDRX cycle length duration as defined in 3GPP 24.008 chapter 10.5.5.32.

`t3512` Optional integer. T3512 timer in seconds. Only present if the NR UE is registered to network.

`enb_plmn` Optional string. eNB PLMN. This field would only be present if the LTE or NB-IoT UE is still in connected mode.

`enb_id` Optional integer. eNB id. This field would only be present if the LTE or NB-IoT UE is still in connected mode.

`enb_ue_id`
Optional integer. eNB UE id. This field would only be present if the LTE or NB-IoT UE is still in connected mode.

`mme_ue_id`
Optional integer. MME UE id. This field would only be present if the LTE or NB-IoT UE is still in connected mode.

`ran_plmn` Optional string. RAN PLMN. This field would only be present if the NR UE is still in connected mode.

`ran_id` Optional integer. RAN id. This field would only be present if the NR UE is still in connected mode.

`ran_ue_id`
Optional integer. RAN UE id. This field would only be present if the NR UE is still in connected mode.

`amf_ue_id`
Optional integer. AMF UE id. This field would only be present if the NR UE is still in connected mode.

`bearers` Array. List of connected default bearers or PDU sessions. Each object has the following definition:

- `erab_id` Optional integer. EPS Bearer ID. Present for LTE or NB-IoT UEs.
- `pdu_session_id`
  Optional integer. 5GS PDU session ID. Present for NR UEs.
- `qos_flow_id`
  Optional integer. 5GS QoS flow ID. Present for NR UEs.
- `ip` String. IPv4 address.
- `ipv6` String. IPv6 address.
- `ul_total_bytes`
  Number. Total uplink transferred bytes.
- `dl_total_bytes`
  Number. Total downlink transferred bytes.
- `apn` String. Access point name.
- `dedicated`
  Array of object. Each object represents a dedicated bearer or non default QoS flow defined as follow:
  - `erab_id` Optional integer. EPS Bearer ID. Present for LTE or NB-IoT UEs.

`qos_flow_id`
: Optional integer. 5GS QoS flow ID. Present for NR UEs.

`ul_total_bytes`
: Number. Total uplink transferred bytes.

`dl_total_bytes`
: Number. Total downlink transferred bytes.

`radio_capabilities`
: GSER string. UE radio access capabilities. Only present if `radio_capabilities` is set to true in request.

`ue_add` Add UE to UE database.
Message definition:

`ue_db` Array. List of UE configuration. See [ue_db], page 28.

`ue_del` Remove UE from the UE database and force disconnect if necessary.
Message definition:

`imsi` String. IMSI of the UE to delete.

`ue_detach`
Force a detach from network.
Message definition:

`imsi` String. IMSI of the UE to detach.

`imei` Optional string (14 or 15 digits). UE IMEI (with or without check digit), required if `multi_sim` is set to true.

`type` Optional number (EPS default = 2 / re-attach not required; 5GS default = 1 / re-registration not required). Set NAS detach request type or de-registration type.

`cause` Optional number (default = 3 / illegal UE). Set EMM or 5GMM cause. The value -1 means that the EMM cause IE is not sent in the NAS Detach Request message or the 5GMM cause is not sent in the NAS Deregistration Request message.

`ue_identity_request`
Force an identification procedure.
Message definition:

`imsi` String. IMSI of the UE.

`imei` Optional string (14 or 15 digits). UE IMEI (with or without check digit), required if `multi_sim` is set to true.

`type` Integer (range 1 to 5). Identity type.

`me_add` Add or update one or several devices in ME database.
Message definition:

`default_status`
: Optional enumeration (whitelisted, blacklisted, greylisted). Defines the default status for devices not explicitly defined in the next objects.

`whitelist`
: Optional array. It contains a list of IMEI (14 digits) or IMEISV (16 digits) whitelisted.

`blacklist`
: Optional array. It contains a list of IMEI (14 digits) or IMEISV (16 digits) blacklisted.

`greylist` Optional array. It contains a list of IMEI (14 digits) or IMEISV (16 digits) greylisted.

`me_del` Remove one or several devices in ME database.
Message definition:

`list` Array of strings. Each entry must be an IMEI (14 digits) or IMEISV (16 digits).

`pws_write`
Start broadcasting Public Warning System message.
Message definition:

`local_id` Number. ID of the message as defined by local_identifier in MME configuration file

`nf` Optional boolean (default = false). If not set, SBC interface is used. If set, N50 interface is used.

`pws_kill` Stop broadcasting Public Warning System message.
Message definition:

`local_id` Number. ID of the message as defined by local_identifier in MME configuration file

`stop_all` Optional boolean. Gives the presence of Stop-All-Indicator IE in the message STOP-WARNING-REQUEST.

`send_warning_indication`
: Optional boolean. Default value is 0. Gives the presence of Send-Stop-Warning-Indication IE in the message STOP WARNING REQUEST.

`nf` Optional boolean (default = false). If not set, SBC interface is used. If set, N50 interface is used.

`cbc_notif_subscribe`
CBC subscription to notification.
Applicable to N50 interface only. Message definition:

`notify_cbk_uri`
: String. Callback URI on which the N2 information shall be notified.

`info_class`
: Optional enumeration: write-cancel, restart-failure (default = write-cancel). Class of N2 information to which the CBC wants to subscribe.

`cbc_notif_unsubscribe`
CBC unsubscription to notification.
Applicable to N50 interface only. Message definition:

`info_class`
: Optional enumeration: write-cancel, restart-failure (default = write-cancel). Class of N2 information to which the CBC wants to unsubscribe.

`enb` Get list of eNB connections.
Response definition:

- `enb_list` Array of object. Each object represents an eNB connection:
  - `plmn` String. PLMN.
  - `eNB_ID_type` String (macro, home, short_macro or long_macro). eNB type.
  - `eNB_ID` Integer. eNB ID.
  - `address` String. eNB IP address and port.
  - `ue_ctx` Number. Number of UE contexts.

`gnb` Get list of gNB connections.
Response definition:

- `gnb_list` Array of object. Each object represents a RAN connection:
  - `plmn` String. PLMN.
  - `RAN_ID_type` String (gNB, ng-eNB or N3IWF). RAN type.
  - `RAN_ID` Integer. RAN ID.
  - `address` String. RAN IP address and port.
  - `ue_ctx` Number. Number of UE contexts.

`s6` Get information regarding the S6a connection.
Response definition:

- `state` String. S6a connection state (disconnected, connecting, connected or inactive).
- `address` String. HSS address and port.
- `host` Optional string. HSS Diameter host identifier retrieved during Capabilities Exchange procedure.
- `realm` Optional string. HSS Diameter realm identifier retrieved during Capabilities Exchange procedure.

`s6connect`
Force S6a connection establishment.
Message definition:

- `addr` Optional string. If not set, the MME will try to connect to the previously configured address

`s6disconnect`
Force S6a connection release.

`s13` Get information regarding the S13 connection.
Response definition:

- `state` String. S13 connection state (disconnected, connecting, connected or inactive).
- `address` String. EIR address and port.

`host` Optional string. EIR Diameter host identifier retrieved during Capabilities Exchange procedure.

`realm` Optional string. EIR Diameter realm identifier retrieved during Capabilities Exchange procedure.

`s13connect`
Force S13 connection establishment.
Message definition:

`addr` Optional string. If not set, the MME will try to connect to the previously configured address

`s13disconnect`
Force S13 connection release.

`sgs` Get information regarding the SGs connection.
Response definition:

`state` String. SGs connection state (disconnected, connecting, connected or inactive).

`address` String. MSC/VLR address and port.

`sgsconnect`
Force SGs connection establishment.
Message definition:

`addr` Optional string. If not set, the MME will try to connect to the previously configured address

`sgsdisconnect`
Force SGs connection release.

`sbc` Get list of CBC connections.
Response definition:

`cbc_list` Array of object. Each object represents a CBC connection:

`address` String. CBC address and port.

`n8` Get information regarding the N8 connections.
Response definition:

`client_connections`
Array of object. Each object represents a N8 client connection.

`state` String. N8 connection state (disconnected, connecting, handshake, connected or inactive).

`address` String. UDM address and port.

`server_connections`
Array of object. Each object represents a N8 server connection.

`address` String. UDM address and port.

`n8connect`
Force N8 connections establishment.
Message definition:

`addr` Optional string. If not set, the AMF will try to connect to the previously configured address

`n8disconnect`
: Force N8 connections release.

`n12`
: Get information regarding the N12 connections.
Response definition:

`client_connections`
: Array of object. Each object represents a N12 client connection.

`state`
: String. N12 connection state (disconnected, connecting, handshake, connected or inactive).

`address`
: String. AUSF address and port.

`n12connect`
: Force N12 connections establishment.
Message definition:

`addr`
: Optional string. If not set, the AMF will try to connect to the previously configured address

`n12disconnect`
: Force N12 connections release.

`n17`
: Get information regarding the N17 connections.
Response definition:

`client_connections`
: Array of object. Each object represents a N17 client connection.

`state`
: String. N17 connection state (disconnected, connecting, handshake, connected or inactive).

`address`
: String. EIR address and port.

`n17connect`
: Force N17 connections establishment.
Message definition:

`addr`
: Optional string. If not set, the AMF will try to connect to the previously configured address

`n17disconnect`
: Force N17 connections release.

`n50`
: Get information regarding the N50 connections.
Response definition:

`client_connections`
: Array of object. Each object represents a N50 client connection.

`state`
: String. N50 connection state (disconnected, connecting, handshake, connected or inactive).

`address`
: String. CBC address and port.

`server_connections`
: Array of object. Each object represents a N50 server connection.

`address`
: String. CBC address and port.

`ue_activate_dedicated_bearer`

Trigger a network initiated dedicated EPS bearer activation or a 5GS QoS flow activation.
Message definition:

`imsi` String. UE IMSI.

`imei` Optional string (14 or 15 digits). UE IMEI (with or without check digit), required if `multi_sim` is set to true.

`apn` String. APN of the default EPS bearer associated to the dedicated one.

`qci` Integer (range 1 to 255). QoS Class Identifier of the E-RAB, or 5QI of the QoS flow.

`priority_level`
Optional integer (1 to 15, default 15). Priority level.

`pre_emption_capability`
Optional enumeration (`shall_not_trigger_pre_emption` or `may_trigger_pre_emption`, default `shall_not_trigger_pre_emption`).

`pre_emption_vulnerability`
Optional enumeration (`not_pre_emptable` or `pre_emptable`, default `not_pre_emptable`).

`filters` Array. See [TFT], page 25.

`gbr` Optional object. See [GBR], page 25.

`transaction_identifier`
Optional integer (range 0 to 127). If present, the transaction identifier IE is put in the EPS bearer activation message.

`llc_sapi` Optional integer (range 0 to 15). If present, the LLC service access point identifier IE is put in the EPS bearer activation message.

`radio_priority`
Optional integer (range 0 to 7). If present, the radio priority IE is put in the EPS bearer activation message.

`packet_flow_identifier`
Optional integer (range 0 to 127). If present, the packet flow identifier IE is put in the EPS bearer activation message.

`sm_qos` Optional string. If present, the quality of service IE is put in the EPS bearer activation message. The string must contain the hexadecimal representation of the IE without its IEI and length.

Response definition:

`erab_id` Integer. Allocated ERAB identity for this dedicated EPS bearer. Sent if the procedure if for EPS.

`pdu_session_id`
Integer. PDU session identifier associated to the QoS flow identifier. Sent if the procedure if for 5GS.

`qos_flow_id`
Integer. Allocated QoS flow identifier for this bearer. Sent if the procedure if for 5GS.

`ue_modify_bearer`
: Trigger a network initiated EPS bearer modification.
Message definition:

  `imsi` String. UE IMSI.

  `imei` Optional string (14 or 15 digits). UE IMEI (with or without check digit), required if `multi_sim` is set to true.

  `erab_id` Integer. ERAB identity of the bearer to be modified.

  `qos` Optional objet. If present a QoS modification is done. It should contain the following objects:

    `qci` Integer (range 1 to 255). QoS Class Identifier of the E-RAB.

    `priority_level`
    Optional integer (1 to 15, default 15). Priority level.

    `pre_emption_capability`
    Optional enumeration (`shall_not_trigger_pre_emption` or `may_trigger_pre_emption`, default `shall_not_trigger_pre_emption`).

    `pre_emption_vulnerability`
    Optional enumeration (`not_pre_emptable` or `pre_emptable`, default `not_pre_emptable`).

    `gbr` Optional object. See [GBR], page 25.

  `filters` Array. Contains the new TFT after modification. See [TFT], page 25.

  `llc_sapi` Optional integer (range 0 to 15). If present, the LLC service access point identifier IE is put in the EPS bearer activation message.

  `radio_priority`
  Optional integer (range 0 to 7). If present, the radio priority IE is put in the EPS bearer activation message.

  `packet_flow_identifier`
  Optional integer (range 0 to 127). If present, the packet flow identifier IE is put in the EPS bearer activation message.

  `sm_qos` Optional string. If present, the quality of service IE is put in the EPS bearer activation message. The string must contain the hexadecimal representation of the IE without its IEI and length.

  `p_cscf` Optional boolean. Adds the P-CSCF addresses to the PCO information element of the modify EPS bearer context request message.

  Response definition:

  `erab_id` Integer. ERAB identity of the EPS bearer.

`ue_modify_pdu_session`
: Trigger a network initiated PDU session modification.
Message definition:

  `imsi` String. UE IMSI.

  `imei` Optional string (14 or 15 digits). UE IMEI (with or without check digit), required if `multi_sim` is set to true.

`pdu_session_id`
: Integer. PDU session identity of the PDU session to be modified.

`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.

  `qfi` Range: 0 to 63. QoS flow identifier.

  `filters` Array of packet filters. See [TFT], page 25.

`qos_flow` Optional object. QoS flow parameters for the qfi. Contains the following items:

  `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 25.

`p_cscf` Optional boolean. Adds the P-CSCF addresses to the ePCO information element of the PDU session modification commmand message.

`ue_deactivate_bearer`
: Trigger a network initiated default or dedicated EPS bearer deactivation, or a 5GS QoS flow deactivation.
Message definition:

  `imsi` String. UE IMSI.

  `imei` Optional string (14 or 15 digits). UE IMEI (with or without check digit), required if `multi_sim` is set to true.

  `erab_id` Optional integer. ERAB identity of the bearer to be released. Must be present for an EPS procedure.

  `esm_cause`
  : Optional integer (default = 36). ESM cause for the message. Can be present for an EPS procedure.

  `pdu_session_id`
  : Optional integer. PDU session identifier of the QoS flow to release. Must be present for a 5GS procedure.

  `qos_flow_id`
  : Optional integer. QoS flow identifier to release. Must be present for a 5GS procedure.

  `5gsm_cause`
  : Optional integer (default = 36). 5GSM cause for the message. Can be present for a 5GS procedure.

`non_ip_data`
: Send data over a non IP PDN.
Message definition:

  `imsi` String. UE IMSI.

  `imei` Optional string (14 or 15 digits). UE IMEI (with or without check digit), required if `multi_sim` is set to true.

`erab_id` Optional integer. ERAB identity of the non IP default bearer. Used for LTE or NB-IoT UEs.

`pdu_session_id`
Optional integer. PDU session ID. Used for NR UEs.

`data` String. ASCII representation of the data hexadecimal dump.

`generic_nas_transport`
Send an EPS downlink generic NAS transport message.
Message definition:

`imsi` String. UE IMSI.

`imei` Optional string (14 or 15 digits). UE IMEI (with or without check digit), required if `multi_sim` is set to true.

`type` Integer (range: 0 to 255). Generic message container type information element.

`payload` String. ASCII representation of the generic message container hexadecimal dump.

`add_info` Optional string. ASCII representation of the additional information hexadecimal dump.

`5gs_nas_transport`
Send an 5GS downlink NAS transport message for LPP, SOR, UE policy or UE parameters update.
Message definition:

`imsi` String. UE IMSI.

`imei` Optional string (14 or 15 digits). UE IMEI (with or without check digit), required if `multi_sim` is set to true.

`type` Integer (range: 3 to 6). Payload container type information element.

`payload` String. ASCII representation of the payload container hexadecimal dump.

`add_info` Optional string. ASCII representation of the additional information hexadecimal dump for LPP.

`reset_ue_pos_stored_info`
Send a test procedure reset UE positioning stored information message.
Message definition:

`imsi` String. UE IMSI.

`imei` Optional string (14 or 15 digits). UE IMEI (with or without check digit), required if `multi_sim` is set to true.

`techno` Integer (range: 0 to 255). UE positioning technology as sepcified in 3GPP 36.509 chapter 6.9.

`mt_cs_paging`
Trigger a CS paging.
Message definition:

`imsi` String. UE IMSI.

6.7 LTE events

Following events are sent by MME if they have been registered on WebSocket.

`non_ip_data`
: Generated by data reception over a non IP PDN.

  `imsi` String. UE IMSI.

  `imei` Optional string. UE IMEI, sent if `multi_sim` is set to true.

  `erab_id` Optional integer. ERAB identity of the non IP default bearer. Used for LTE or NB-IoT UEs.

  `pdu_session_id`
  : Optional integer. PDU session ID. Used for NR UEs.

  `data` String. ASCII representation of the data hexadecimal dump.

`generic_nas_transport`
: Generated when receiving an EPS uplink generic NAS transport message.
  Message definition:

  `imsi` String. UE IMSI.

  `imei` Optional string. UE IMEI, sent if `multi_sim` is set to true.

  `type` Integer. Generic message container type information element.

  `payload` String. ASCII representation of the generic message container hexadecimal dump.

  `add_info` Optional string. ASCII representation of the additional information hexadecimal dump.

`5gs_nas_transport`
: Generated when receiving a 5GS uplink NAS transport message for LPP, SOR, UE policy or UE parameters update.
  Message definition:

  `imsi` String. UE IMSI.

  `imei` Optional string. UE IMEI, sent if `multi_sim` is set to true.

  `type` Integer (range: 3 to 6). Payload container type information element.

  `payload` String. ASCII representation of the payload container hexadecimal dump.

  `add_info` Optional string. ASCII representation of the additional information hexadecimal dump for LPP.

`eps_bearer_notification`
: Generated when an EPS bearer is opened or released.
  Message definition:

  `imsi` Optional string. UE IMSI. Might not be present in case of emergency call.

  `imei` Optional string. UE IMEI, sent if `multi_sim` is set to true.

  `apn` String. Access point name.

  `pdn_type` Enumeration (ipv4, ipv6, ipv4v6, non-ip). PDN type.

`activated`
: Boolean. True on EPS bearer establishment, false on EPS bearer release.

`ipv4_address`
: Optional string. IPv4 address allocated to the UE.

`ipv6_prefix`
: Optional string. IPv6 prefix allocated to the UE.

`erab_id` Integer. ERAB identity.

`linked_erab_id`
: Optional integer. ERAB identity of the default EPS bearer. Present when the EPS bearer opened is a dedicated bearer.

`dl_bytes` Optional integer. Number of dowlink bytes sent to the UE. Present when `activated` is set to false.

`ul_bytes` Optional integer. Number of uplink bytes received from the UE. Present when `activated` is set to false.

`start_date`
: Integer. Start date in seconds since 1970-01-01 00:00:00

`duration` Optional number. Duration in seconds of bearer lifetime. Present when `activated` is set to false.

`qos_flow_notification`
: Generated when a QoS flow is opened or released.
Message definition:

`imsi` Optional string. UE IMSI. Might not be present in case of emergency call.

`imei` Optional string. UE IMEI, sent if `multi_sim` is set to true.

`dnn` String. Data network name.

`pdn_type` Enumeration (ipv4, ipv6, ipv4v6, non-ip). PDN type.

`activated`
: Boolean. True on EPS bearer establishment, false on EPS bearer release.

`ipv4_address`
: Optional string. IPv4 address allocated to the UE.

`ipv6_prefix`
: Optional string. IPv6 prefix allocated to the UE.

`pdu_session_id`
: Integer. PDU session identity.

`qos_flow_id`
: Integer. QoS flow identity;

`dl_bytes` Optional integer. Number of dowlink bytes sent to the UE. Present when `activated` is set to false.

`ul_bytes` Optional integer. Number of uplink bytes received from the UE. Present when `activated` is set to false.

`start_date`
: Integer. Start date in seconds since 1970-01-01 00:00:00

`duration`
: Optional number. Duration in seconds of bearer lifetime. Present when `activated` is set to false.

6.8 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"
}
```

7 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.

`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.

`enb` List the connected eNodeBs.

`gnb` List the connected gNodeBs.

`ue [`*`reg`*`]` List all the UE contexts (the UEs can be connected or not). If used with parameter *reg*, only registered UEs will be displayed.

`uectx` List all the active S1 or NG UE contexts.

`pws_write` *`local_id`*
Start broadcasting the ETWS/CMAS message identified by *local_id* on all connected eNodeBs.

`pws_kill` *`local_id`*
Stop broadcasting the ETWS/CMAS message identified by *local_id* on all connected eNodeBs.

`quit` Stop the program and exit.

8 Log file format

8.1 NAS layer

When a NAS message is dumped, the format is:

```
time layer - message
```

When a NAS data PDU is dumped (debug level), the format is:

```
time layer dir MME_UE_ID message_type
        long_content
```

`time` Time using the selected format

`layer` Indicate the layer (`[NAS]` here).

`dir` UL (uplink) or DL (downlink).

`MME_UE_ID`
MME S1AP UE identifier (hexadecimal).

`message_type`
NAS message type.

`long_content`
Full content of the NAS message if `nas.max_size > 0`.

8.2 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`.

8.3 S1AP, NGAP, SBcAP and GTP-U layers

When a message is dumped, the format is:

```
time layer - message
```

When a data PDU is dumped (debug level), the format is:

```
time layer dir ip_address short_content
        long_content
```

`time` Time using the selected format.

`layer` Indicate the layer (`[S1AP]` or `[NGAP]` or `[GTPU]` or `[SBCAP]` here).

`dir` Direction: `TO` or `FROM`.

`ip_address`
source or destination IP address, depending on the `dir` field.

`short_content`
: Single line content.

`long_content`
: - S1AP or NGAP or SBCAP: full ASN.1 content of the message if `layer.max_size > 0`.
  - GTPU: hexadecimal dump of the message if `layer.max_size > 0`.

9 FAQ

9.1 Traffic control

I want to generate errors, limit bandwidth, introduce latency...

Easiest and most powerful way is to do this at IP level using the *tc* Linux command.
There are various tutorials on the internet but it is not a piece of cake so here are some common commands to handle simple case.

First, *tc* will operate at Linux interface level, which means that for LTE we will control the *tun0* interface created by MME.
Note that this configuration will be dropped each time you restart the MME so if you want to set it automatically and keep it we recommand to place the commands inside *config/mme-ifup* (See [tun_setup_script], page 12).

- To limit overall bandwidth to 2mbps:

```
tc qdisc add dev tun0 root handle 1:0 htb default 1
tc class add dev tun0 parent 1:0 classid 1:1 htb rate 2000kbit
```

- To simulate 10% packet loss:

```
tc qdisc add dev tun0 root handle 1: netem loss 10%
```

- To change previous packet loss to 20%:

```
tc qdisc change dev tun0 root handle 1: netem loss 10%
```

- To add 100ms latency with more or less 10ms:

```
tc qdisc add dev tun0 root handle 1: netem delay 100ms 10ms
```

- Same as previous but with a normal distribution:

```
tc qdisc add dev tun0 root handle 1: netem delay 100ms 10ms distribution normal
```

tc is very powerful and you may also chain filters (qdisc), apply them on specific traffic...

10 Known limitations

We present here the known limitations of LTEMME:

- A single PLMN is supported.
- No interface with external SGW is implemented.

11 License

`ltemme` is copyright (C) 2012-2020 Amarisoft. Its redistribution without authorization is prohibited.

`ltemme` is available without any express or implied warranty. In no event will Amarisoft be held liable for any damages arising from the use of this software.

For more information on licensing, please refer to `license.pdf` file.

Abbreviations

5GC	5G Core Network
5GS	5G System
5QI	5G QoS Identifier
AMF	Access and Mobility Management Function
APN	Access Point Name
AUSF	Authentication Server Function
DCNR	Dual Connectivity with NR
DL	Downlink
DNN	Data Network Name
E-RAB	E-UTRAN Radio Access Bearer
E-UTRA	Evolved UMTS Terrestrial Radio Access
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
EIR	Equipment Identity Register
EPC	Evolved Packet Core
ePCO	Extended Protocol Configuration Options
EPS	Evolved Packet System
HSS	Home Subscriber Server
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber Identity
LTE	Long Term Evolution
MME	Mobility Management Entity
NAS	Non Access Stratum
NR	New Radio
PCO	Protocol Configuration Options
PCRF	Policy and Charging Enforcement Function
PDN	Packet Data Network
PDU	Protocol Data Unit
PGW	Packet Data Network Gateway
QCI	Quality of Service (QoS) Class Identifier
QoS	Quality of Service
SDU	Service Data Unit
SGW	Serving Gateway
SMF	Session Management Function
TMSI	Temporary Mobile Subscriber Identity

UE	User Equipment
UL	Uplink
UPF	User Plane Function
USIM	Universal Subscriber Identity Module
VoLTE	Voice over LTE