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OsmoHLR User Manual

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The Asciidoc source code of this manual can be found at http://git.osmocom.org/osmo-gsm-manuals/

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Contents

1 Foreword

Digital cellular networks based on the GSM specification were designed in the late 1980ies and first deployed in the early 1990ies in Europe. Over the last 25 years, hundreds of networks were established globally and billions of subscribers have joined the associated networks.

The technological foundation of GSM was based on multi-vendor interoperable standards, first created by government bodies within CEPT, then handed over to ETSI, and now in the hands of 3GPP. Nevertheless, for the first 17 years of GSM technology, the associated protocol stacks and network elements have only existed in proprietary *black-box* implementations and not as Free Software.

In 2008 Dieter Spaar and I started to experiment with inexpensive end-of-life surplus Siemens GSM BTSs. We learned about the A-bis protocol specifications, reviewed protocol traces and started to implement the BSC-side of the A-bis protocol as something originally called `bs11-abis`. All of this was *just for fun*, in order to learn more and to boldly go where no Free Software developer has gone before. The goal was to learn and to bring Free Software into a domain that despite its ubiquity had not yet seen and Free / Open Source software implementations.

`bs11-abis` quickly turned into `bsc-hack`, then *OpenBSC* and its *OsmoNITB* variant: A minimal implementation of all the required functionality of an entire GSM network, exposing A-bis towards the BTS. The project attracted more interested developers, and surprisingly quickly also commercial interest, contribution and adoption. This allowed adding support for more BTS models.

After having implemented the network-side GSM protocol stack in 2008 and 2009, in 2010 the same group of people set out to create a telephone-side implementation of the GSM protocol stack. This established the creation of the Osmocom umbrella project, under which OpenBSC and the OsmocomBB projects were hosted.

Meanwhile, more interesting telecom standards were discovered and implemented, including TETRA professional mobile radio, DECT cordless telephony, GMR satellite telephony, some SDR hardware, a SIM card protocol tracer and many others.

Increasing commercial interest particularly in the BSS and core network components has lead the way to 3G support in Osmocom, as well as the split of the minimal *OsmoNITB* implementation into separate and fully featured network components: OsmoBSC, OsmoMSC, OsmoHLR, OsmoMGW and OsmoSTP (among others), which allow seamless scaling from a simple "Network In The Box" to a distributed installation for serious load.

It has been a most exciting ride during the last eight-odd years. I would not have wanted to miss it under any circumstances.

— Harald Welte, Osmocom.org and OpenBSC founder, December 2017.

1.1 Acknowledgements

My deep thanks to everyone who has contributed to Osmocom. The list of contributors is too long to mention here, but I'd like to call out the following key individuals and organizations, in no particular order:

- Dieter Spaar for being the most amazing reverse engineer I've met in my career
- Holger Freyther for his many code contributions and for shouldering a lot of the maintenance work, setting up Jenkins - and being crazy enough to co-start sysmocom as a company with me ;)
- Andreas Eversberg for taking care of Layer2 and Layer3 of OsmocomBB, and for his work on OsmoBTS and OsmoPCU
- Sylvain Munaut for always tackling the hardest problems, particularly when it comes closer to the physical layer
- Chaos Computer Club for providing us a chance to run real-world deployments with tens of thousands of subscribers every year
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- sysmocom, for hosting and funding a lot of Osmocom development, the annual Osmocom Developer Conference and releasing this manual.

- Jan Luebbe, Stefan Schmidt, Daniel Willmann, Pablo Neira, Nico Golde, Kevin Redon, Ingo Albrecht, Alexander Huemer, Alexander Chemeris, Max Suraev, Tobias Engel, Jacob Erlbeck, Ivan Kluchnikov

May the source be with you!

— Harald Welte, Osmocom.org and OpenBSC founder, January 2016.

1.2 Endorsements

This version of the manual is endorsed by Harald Welte as the official version of the manual.

While the GFDL license (see Appendix C) permits anyone to create and distribute modified versions of this manual, such modified versions must remove the above endorsement.

2 Preface

First of all, we appreciate your interest in Osmocom software.

Osmocom is a Free and Open Source Software (FOSS) community that develops and maintains a variety of software (and partially also hardware) projects related to mobile communications.

Founded by people with decades of experience in community-driven FOSS projects like the Linux kernel, this community is built on a strong belief in FOSS methodology, open standards and vendor neutrality.

2.1 FOSS lives by contribution!

If you are new to FOSS, please try to understand that this development model is not primarily about “free of cost to the GSM network operator”, but it is about a collaborative, open development model. It is about sharing ideas and code, but also about sharing the effort of software development and maintenance.

If your organization is benefitting from using Osmocom software, please consider ways how you can contribute back to that community. Such contributions can be many-fold, for example

- sharing your experience about using the software on the public mailing lists, helping to establish best practises in using/operating it,
- providing qualified bug reports, work-arounds
- sharing any modifications to the software you may have made, whether bug fixes or new features, even experimental ones
- providing review of patches
- testing new versions of the related software, either in its current “master” branch or even more experimental feature branches
- sharing your part of the maintenance and/or development work, either by donating developer resources or by (partially) funding those people in the community who do.

We’re looking forward to receiving your contributions.

2.2 Osmocom and sysmocom

Some of the founders of the Osmocom project have established *sysmocom - systems for mobile communications GmbH* as a company to provide products and services related to Osmocom.

sysmocom and its staff have contributed by far the largest part of development and maintenance to the Osmocom mobile network infrastructure projects.

As part of this work, sysmocom has also created the manual you are reading.

At sysmocom, we draw a clear line between what is the Osmocom FOSS project, and what is sysmocom as a commercial entity. Under no circumstances does participation in the FOSS projects require any commercial relationship with sysmocom as a company.

2.3 Corrections

We have prepared this manual in the hope that it will guide you through the process of installing, configuring and debugging your deployment of cellular network infrastructure elements using Osmocom software. If you do find errors, typos and/or omissions, or have any suggestions on missing topics, please do take the extra time and let us know.

2.4 Legal disclaimers

2.4.1 Spectrum License

As GSM and UMTS operate in licensed spectrum, please always double-check that you have all required licenses and that you do not transmit on any ARFCN or UARFCN that is not explicitly allocated to you by the applicable regulatory authority in your country.

Warning
Depending on your jurisdiction, operating a radio transmitter without a proper license may be considered a felony under criminal law!

2.4.2 Software License

The software developed by the Osmocom project and described in this manual is Free / Open Source Software (FOSS) and subject to so-called *copyleft* licensing.

Copyleft licensing is a legal instrument to ensure that this software and any modifications, extensions or derivative versions will always be publicly available to anyone, for any purpose, under the same terms as the original program as developed by Osmocom.

This means that you are free to use the software for whatever purpose, make copies and distribute them - just as long as you ensure to always provide/release the *complete and corresponding* source code.

Every Osmocom software includes a file called `COPYING` in its source code repository which explains the details of the license. The majority of programs is released under GNU Affero General Public License, Version 3 (AGPLv3).

If you have any questions about licensing, don't hesitate to contact the Osmocom community. We're more than happy to clarify if your intended use case is compliant with the software licenses.

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2.4.5 Documentation License

Please see Appendix C for further information.

3 Introduction

3.1 Required Skills

Please note that even while the capital expenses of running mobile networks has decreased significantly due to Osmocom software and associated hardware like sysmoBTS, GSM networks are still primarily operated by large GSM operators.

Neither the GSM specification nor the GSM equipment was ever designed for networks to be installed and configured by anyone but professional GSM engineers, specialized in their respective area like radio planning, radio access network, back-haul or core network.

If you do not share an existing background in GSM network architecture, GSM protocols, correctly installing, configuring and optimizing your GSM network will be tough, irrespective whether you use products with Osmocom software or those of traditional telecom suppliers.

GSM knowledge has many different fields, from radio planning through site installation to core network configuration/administration.

The detailed skills required will depend on the type of installation and/or deployment that you are planning, as well as its associated network architecture. A small laboratory deployment for research at a university is something else than a rural network for a given village with a handful of cells, which is again entirely different from an urban network in a dense city.

Some of the useful skills we recommend are:

- general understanding about RF propagation and path loss in order to estimate coverage of your cells and do RF network planning.
- general understanding about GSM network architecture, its network elements and key transactions on the Layer 3 protocol
- general understanding about voice telephony, particularly those of ISDN heritage (Q.931 call control)
- understanding of GNU/Linux system administration and working on the shell
- understanding of TCP/IP networks and network administration, including tcpdump, tshark, wireshark protocol analyzers.
- ability to work with text based configuration files and command-line based interfaces such as the VTY of the Osmocom network elements

3.2 Getting assistance

If you do have a support package / contract with sysmocom (or want to get one), please contact support@sysmocom.de with any issues you may have.

If you don't have a support package / contract, you have the option of using the resources put together by the Osmocom community at http://projects.osmocom.org/, checking out the wiki and the mailing-list for community-based assistance. Please always remember, though: The community has no obligation to help you, and you should address your requests politely to them. The information (and software) provided at osmocom.org is put together by volunteers for free. Treat them like a friend whom you're asking for help, not like a supplier from whom you have bought a service.

4 Overview

This manual should help you getting started with OsmoHLR. It will cover aspects of configuring and running the OsmoHLR.

4.1 About OsmoHLR

OsmoHLR is Osmocom's minimal implementation of a Home Location Register (HLR) for 2G and 3G GSM and UMTS mobile core networks. Its interfaces are:

- GSUP, serving towards OsmoMSC and OsmoSGSN;
- A local SQLite database;
- The Osmocom typical telnet VTY and CTRL interfaces.

Originally, the OpenBSC project's OsmoNITB all-in-one implementation had an integrated HLR, managing subscribers and SMS in the same local database. Along with the separate OsmoMSC and its new VLR component, OsmoHLR was implemented from scratch to alleviate various shortcomings of the internal HLR:

- The separate HLR allows using centralized subscriber management for both circuit-switched and packet-switched domains (i.e. one OsmoHLR for both OsmoMSC and OsmoSGSN).
- VLR and HLR brought full UMTS AKA (Authentication and Key Agreement) support, i.e. Milenage authentication in both the full 3G variant as well as the backwards compatible 2G variant.
- In contrast to the OsmoNITB, the specific way the new OsmoMSC's VLR accesses OsmoHLR brings fully asynchronous subscriber database access.

Find the OsmoHLR issue tracker and wiki online at

- https://osmocom.org/projects/osmo-hlr
- https://osmocom.org/projects/osmo-hlr/wiki

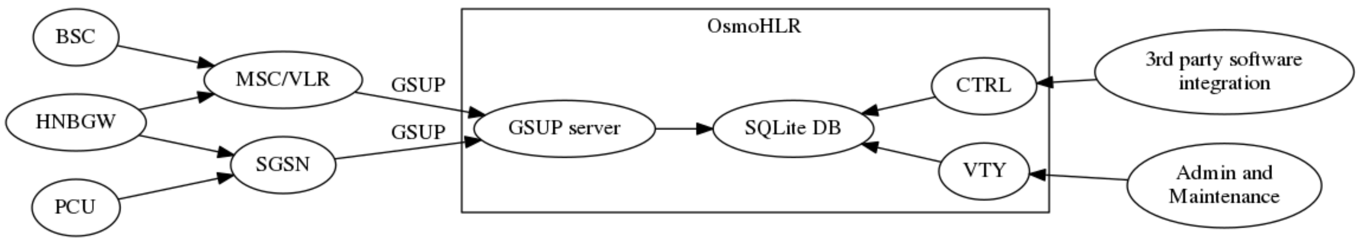


Figure 1: Typical GSM network architecture used with OsmoHLR

5 Running OsmoHLR

The OsmoHLR executable (`osmo-hlr`) offers the following command-line arguments:

5.1 SYNOPSIS

osmo-hlr [-h|-V] [-d *DBGMASK*] [-D] [-c *CONFIGFILE*] [-s] [-T] [-e *LOGLEVEL*] [-l *DATABASE*]

5.2 OPTIONS

-h, --help
Print a short help message about the supported options

-V, --version
Print the compile-time version number of the OsmoBTS program

-d, --debug *DBGMASK,DBGLEVELS*
Set the log subsystems and levels for logging to stderr. This has mostly been superseded by VTY-based logging configuration, see Section 9 for further information.

-D, --daemonize
Fork the process as a daemon into background.

-c, --config-file *CONFIGFILE*
Specify the file and path name of the configuration file to be used. If none is specified, use `osmo-hlr.cfg` in the current working directory.

-s, --disable-color
Disable colors for logging to stderr. This has mostly been deprecated by VTY based logging configuration, see Section 9 for more information.

-T, --timestamp
Enable time-stamping of log messages to stderr. This has mostly been deprecated by VTY based logging configuration, see Section 9 for more information.

-e, --log-level *LOGLEVEL*
Set the global log level for logging to stderr. This has mostly been deprecated by VTY based logging configuration, see Section 9 for more information.

-l, --database *DATABASE*
Specify the file name of the SQLite3 database to use as HLR/AUC storage

5.3 Bootstrap the Database

If no database exists yet, OsmoHLR will automatically create and bootstrap a database file with empty tables. If no `-l` command-line option is provided, this database file will be created in the current working directory.

Alternatively, you may use the `osmo-hlr-db-tool`, which is installed along with `osmo-hlr`, to bootstrap an empty database, or to migrate subscriber data from an old *OsmoNITB* database. See `osmo-hlr-db-tool --help`.

5.4 Multiple instances

Running multiple instances of `osmo-hlr` on the same computer is possible if all interfaces (VTY, CTRL) are separated using the appropriate configuration options. The IP based interfaces are binding to local host by default. In order to separate the processes, the user has to bind those services to specific but different IP addresses and/or ports.

The VTY and the Control interface can be bound to IP addresses from the loopback address range, for example:

```
line vty
 bind 127.0.0.2
ctrl
 bind 127.0.0.2
```

The GSUP interface can be bound to a specific IP address by the following configuration options:

```
hlr
 gsup
  bind ip 10.23.42.1
```


Note
At the time of writing, OsmoHLR lacks a config option to change the GSUP port, which is by default TCP port 4222.

6 Managing Subscribers

Subscribers are kept in a local SQLite database file and can be managed via VTY and CTRL interfaces.

This section provides some examples; also refer to the OsmoHLR VTY reference manual [vty-ref-osmohlr] as well as the Control interface described in Section 10.

6.1 Example: Add/Update/Delete Subscriber via VTY

The following telnet VTY session adds a subscriber complete with GSM (2G) and UMTS (3G and 2G) authentication tokens, and finally removes the subscriber again; it assumes that osmo-hlr is running and listening for telnet VTY connections on localhost:

```
$ telnet localhost 4258
OsmoHLR> enable
OsmoHLR# subscriber imsi 123456789023000 create
% Created subscriber 123456789023000
    ID: 1
    IMSI: 123456789023000
    MSISDN: none

OsmoHLR# subscriber imsi 123456789023000 update msisdn 423
% Updated subscriber IMSI='123456789023000' to MSISDN='423'

OsmoHLR# subscriber msisdn 423 update aud3g milenage k deaf0ff1ced0d0dabbedd1ced1cef00d opc ↩
     cededeffacedacefacedbadfadedbeef
OsmoHLR# subscriber msisdn 423 show
    ID: 1
    IMSI: 123456789023000
    MSISDN: 423
    3G auth: MILENAGE
             K=deaf0ff1ced0d0dabbedd1ced1cef00d
             OPC=cededeffacedacefacedbadfadedbeef
             IND-bitlen=5

OsmoHLR# subscriber msisdn 423 update aud2g comp128v3 ki beefedcafefaceacedaddeddecadefee
OsmoHLR# subscriber msisdn 423 show
    ID: 1
    IMSI: 123456789023000
    MSISDN: 423
    2G auth: COMP128v3
             KI=beefedcafefaceacedaddeddecadefee
    3G auth: MILENAGE
             K=deaf0ff1ced0d0dabbedd1ced1cef00d
             OPC=cededeffacedacefacedbadfadedbeef
             IND-bitlen=5

OsmoHLR# subscriber imsi 123456789023000 delete
% Deleted subscriber for IMSI '123456789023000'
```

6.2 Subscriber Parameters

The following parameters are managed for each subscriber of the HLR, modelled roughly after 3GPP TS 23.008, version 13.3.0; note that not all of these parameters are necessarily in active use.

The aud3g table also applies to 2G networks: it provides UMTS AKA tokens for Milenage authentication, which is available both on 3G and 2G networks. On 2G, when both MS and network are R99 capable (like OsmoMSC and OsmoSGSN are), the full UMTS AKA with Milenage keys from aud_3g, using AUTN and extended RES tokens, is available. With pre-R99 MS or network configurations, the GSM AKA compatible variant of Milenage, still using the Milenage keys from aud_3g but transceiving only RAND and SRES, may be applicable. (See 3GPP TS 33.102, chapter 6.8.1, Authentication and key agreement of UMTS subscribers.)

Table 1: OsmoHLR's subscriber parameters

Name	Example	Description
imsi	901700000014701	identity of the SIM/USIM, 3GPP TS 23.008 chapter 2.1.1.1
msisdn	2342123	number to dial to reach this subscriber (multiple MSISDNs can be stored per subscriber), 3GPP TS 23.008 chapter 2.1.2
imeisv	4234234234234275	identity of the mobile device and software version, 3GPP TS 23.008 chapter 2.2.3
aud2g.algo	comp128v3	Authentication algorithm ID for GSM AKA, corresponds to enum osmo_auth_algo
aud2g.ki		Subscriber's secret key (128bit)
aud3g.algo	milenage	Authentication algorithm ID for UMTS AKA (applies to both 3G and 2G networks), corresponds to enum osmo_auth_algo
aud3g.k	(32 hexadecimal digits)	Subscriber's secret key (128bit)
aud3g.op	(32 hexadecimal digits)	Operator's secret key (128bit)
aud3g.opc	(32 hexadecimal digits)	Secret key derived from OP and K (128bit), alternative to using OP which does not disclose OP to subscribers
aud3g.sqn	123	Sequence number of last used key (64bit unsigned)
aud3g.ind_bitlen	5	Nr of index bits at lower SQN end
apn		
vlr_number		3GPP TS 23.008 chapter 2.4.5
hlr_number		3GPP TS 23.008 chapter 2.4.6
sgsn_number		3GPP TS 23.008 chapter 2.4.8.1
sgsn_address		3GPP TS 23.008 chapter 2.13.10
ggsn_number		3GPP TS 23.008 chapter 2.4.8.2
gmlc_number		3GPP TS 23.008 chapter 2.4.9.2
smsc_number		3GPP TS 23.008 chapter 2.4.23
periodic_lu_tmr		3GPP TS 23.008 chapter 2.4.24
periodic_rau_tau_tmr		3GPP TS 23.008 chapter 2.13.115
nam_cs	1	Enable/disable voice access (3GPP TS 23.008 chapter 2.1.1.2: network access mode)
nam_ps	0	Enable/disable data access (3GPP TS 23.008 chapter 2.1.1.2: network access mode)
lmsi		3GPP TS 23.008 chapter 2.1.8
ms_purged_cs	0	3GPP TS 23.008 chapter 2.7.5
ms_purged_ps	1	3GPP TS 23.008 chapter 2.7.6

7 Unstructured Supplementary Services Data (USSD)

The *Unstructured Supplementary Services Data (USSD)* is one service within 2G/3G networks next to other services such as circuit-switched voice, packet-switched data and SMS (Short Message Service).

It is on an abstract level quite similar to SMS in that USSD can be used to send textual messages. However, there are the following differences:

- USSD is between the MS (phone) and an USSD application on the network, while SMS is primarily between two subscribers identified by their MSISDN
- USSD is faster, as it doesn't suffer from the complicated three-layer CP/RP/TP protocol stack of SMS with it's acknowledgement of the acknowledged acknowledgement.
- USSD is session-oriented, i.e. a dialogue/session between subscriber and application can persist for the transfer of more than one message. The dedicated radio channel on the RAN remains established throughout that dialogue.

7.1 USSD in Osmocom

Until August 2018, OsmoMSC contained some minimalistic internal USSD handling with no ability to attach/extend it with external USSD applications.

From August 2018 onwards, OsmoMSC doesn't contain any internal USSD handlers/applications anymore. Instead, all USSD is transported to/from OsmoHLR via the GSUP protocol.

OsmoHLR contains some intenal USSD handlers and can route USSD messages to any number of external USSD entities (EUSEs). The EUSE also use GSUP to communicate USSD from/to OsmoHLR.

Each EUSE is identified by its name. The name consists of a single-word string preceding a currently fixed ("-00-00-00-00-00-00") suffix. There is no authentication between EUSE and OsmoHLR: Any client program able to connect to the GSUP port of OsmoHLR can register as any EUSE (name).

NOTE
We plan to remove the requirement for this suffix as soon as we are done resolving all more important issues.

7.2 USSD Configuration

USSD configuration in OsmoHLR happens within the `hlr` VTY node.

`euse foobar-00-00-00-00-00-00` defines an EUSE with the given name `foobar`

`ussd route prefix *123 external foobar-00-00-00-00-00-00` installs a prefix route to the named EUSE. All USSD short codes starting with *123 will be routed to the named EUSE.

`ussd route prefix *#100# internal own-msisdn` installs a prefix route to the named internal USSD handler. There above command will restore the old behavior, in which *100 will return a text message containing the subscribers own phone number. There is one other handler called `own-imsi` which will return the IMSI instead of the MSISDN.

`ussd default-route external foobar-00-00-00-00-00-00` installs a default route to the named EUSE. This means that all USSD codes for which no more specific route exists will be routed to the named EUSE.

7.3 Example EUSE program

We have provided an example EUSE developed in C language using existing Osmocom libraries for GSUP protocol handling and USSD encoding/decoding. It will register as `foobar` EUSE to OsmoHLR on localhost. You can run it on a different machine by specifying e.g. `osmo-euse-demo 1.2.3.4 5678` to make it connect to OsmoHLR on IP address 1.2.3.4 and GSUP/TCP port 5678.

The idea is that you can use this as a template to develop your own USSD applications, or any gateways to other protocols or interfaces.

You can find it in `osmo-hlr/src/osmo-euse-demo.c` or online by following the link to http://git.osmocom.org/osmo-hlr/tree/src/osmo-euse-demo.c

This demonstration program will echo back any USSD message sent/routed to it, quoted like *You sent "…"*.

8 The Osmocom VTY Interface

All human interaction with Osmocom software is typically performed via an interactive command-line interface called the *VTY*.

Note
Integration of your programs and scripts should **not** be done via the telnet VTY interface, which is intended for human interaction only: the VTY responses may arbitrarily change in ways obvious to humans, while your scripts' parsing will likely break often. For external software to interact with Osmocom programs (besides using the dedicated protocols), it is strongly recommended to use the Control interface instead of the VTY, and to actively request / implement the Control interface commands as required for your use case.

The interactive telnet VTY is used to

- explore the current status of the system, including its configuration parameters, but also to view run-time state and statistics,
- review the currently active (running) configuration,
- perform interactive changes to the configuration (for those items that do not require a program restart),
- store the current running configuration to the config file,
- enable or disable logging; to the VTY itself or to other targets.

The Virtual Tele Type (VTY) has the concept of *nodes* and *commands*. Each command has a name and arguments. The name may contain a space to group several similar commands into a specific group. The arguments can be a single word, a string, numbers, ranges or a list of options. The available commands depend on the current node. there are various keyboard shortcuts to ease finding commands and the possible argument values.

Configuration file parsing during program start is actually performed the VTY's CONFIG node, which is also available in the telnet VTY. Apart from that, the telnet VTY features various interactive commands to query and instruct a running Osmocom program. A main difference is that during config file parsing, consistent indenting of parent vs. child nodes is required, while the interactive VTY ignores indenting and relies on the *exit* command to return to a parent node.

Note
In the *CONFIG* node, it is not well documented which commands take immediate effect without requiring a program restart. To save your current config with changes you may have made, you may use the `write file` command to **overwrite** your config file with the current configuration, after which you should be able to restart the program with all changes taking effect.

This chapter explains most of the common nodes and commands. A more detailed list is available in various programs' VTY reference manuals, e.g. see [vty-ref-osmomsc].

There are common patterns for the parameters, these include IPv4 addresses, number ranges, a word, a line of text and choice. The following will explain the commonly used syntactical patterns:

Table 2: VTY Parameter Patterns

Pattern	Example	Explanation
`A.B.C.D`	`127.0.0.1`	An IPv4 address
`TEXT`	`example01`	A single string without any spaces, tabs
`.TEXT`	`Some information`	A line of text
`(OptionA|OptionB|OptionC)`	`OptionA`	A choice between a list of available options
`<0-10>`	`5`	A number from a range

8.1 Accessing the telnet VTY

The VTY of a given Osmocom program is implemented as a telnet server, listening to a specific TCP port.

Please see Appendix A to check for the default TCP port number of the VTY interface of the specific Osmocom software you would like to connect to.

As telnet is insecure and offers neither strong authentication nor encryption, the VTY by default only binds to localhost (127.0.0.1) and will thus not be reachable by other hosts on the network.

> **Warning**
> By default, any user with access to the machine running the Osmocom software will be able to connect to the VTY. We assume that such systems are single-user systems, and anyone with local access to the system also is authorized to access the VTY. If you require stronger security, you may consider using the packet filter of your operating system to restrict access to the Osmocom VTY ports further.

8.2 VTY Nodes

The VTY by default has the following minimal nodes:

VIEW
When connecting to a telnet VTY, you will be on the *VIEW* node. As its name implies, it can only be used to view the system status, but it does not provide commands to alter the system state or configuration. As long as you are in the non-privileged *VIEW* node, your prompt will end in a > character.

ENABLE
The *ENABLE* node is entered by the `enable` command, from the *VIEW* node. Changing into the *ENABLE* node will unlock all kinds of commands that allow you to alter the system state or perform any other change to it. The *ENABLE* node and its children are signified by a # character at the end of your prompt.
You can change back from the *ENABLE* node to the *VIEW* node by using the `disable` command.

CONFIG
The *CONFIG* node is entered by the `configure terminal` command from the *ENABLE* node. The config node is used to change the run-time configuration parameters of the system. The prompt will indicate that you are in the config node by a `(config)#` prompt suffix.
You can always leave the *CONFIG* node or any of its children by using the `end` command.
This node is also automatically entered at the time the configuration file is read. All configuration file lines are processed as if they were entered from the VTY *CONFIG* node at start-up.

Other
Depending on the specific Osmocom program you are running, there will be few or more other nodes, typically below the *CONFIG* node. For example, the OsmoBSC has nodes for each BTS, and within the BTS node one for each TRX, and within the TRX node one for each Timeslot.

8.3 Interactive help

The VTY features an interactive help system, designed to help you to efficiently navigate is commands.

> **Note**
> The VTY is present on most Osmocom GSM/UMTS/GPRS software, thus this chapter is present in all the relevant manuals. The detailed examples below assume you are executing them on the OsmoNITB VTY. They will work in similar fashion on the other VTY interfaces, while the node structure will differ in each program.

8.3.1 The question-mark (?) command

If you type a single ? at the prompt, the VTY will display possible completions at the exact location of your currently entered command.

If you type ? at an otherwise empty command (without having entered even only a partial command), you will get a list of the first word of all possible commands available at this node:

Example: Typing ? at start of OsmoNITB prompt

```
OpenBSC> ❶
  show        Show running system information
  list        Print command list
  exit        Exit current mode and down to previous mode
  help        Description of the interactive help system
  enable      Turn on privileged mode command
  terminal    Set terminal line parameters
  who         Display who is on vty
  logging     Configure log message to this terminal
  sms         SMS related commands
  subscriber  Operations on a Subscriber
```

❶ Type ? here at the prompt, the ? itself will not be printed.

If you have already entered a partial command, ? will help you to review possible options of how to continue the command. Let's say you remember that show is used to investigate the system status, but you don't remember the exact name of the object. Hitting ? after typing show will help out:

Example: Typing ? after a partial command

```
OpenBSC> show ❶
  version       Displays program version
  online-help   Online help
  history       Display the session command history
  network       Display information about a GSM NETWORK
  bts           Display information about a BTS
  trx           Display information about a TRX
  timeslot      Display information about a TS
  lchan         Display information about a logical channel
  paging        Display information about paging requests of a BTS
  paging-group  Display the paging group
  logging       Show current logging configuration
  alarms        Show current logging configuration
  stats         Show statistical values
  e1_driver     Display information about available E1 drivers
  e1_line       Display information about a E1 line
  e1_timeslot   Display information about a E1 timeslot
  subscriber    Operations on a Subscriber
  statistics    Display network statistics
  sms-queue     Display SMSqueue statistics
  smpp          SMPP Interface
```

❶ Type ? after the show command, the ? itself will not be printed.

You may pick the network object and type ? again:

Example: Typing ? after show network

```
OpenBSC> show network
  <cr>
```

By presenting <cr> as the only option, the VTY tells you that your command is complete without any remaining arguments being available, and that you should hit enter, a.k.a. "carriage return".

8.3.2 TAB completion

The VTY supports tab (tabulator) completion. Simply type any partial command and press `<tab>`, and it will either show you a list of possible expansions, or completes the command if there's only one choice.

Example: Use of <tab> pressed after typing only s as command

```
OpenBSC> s❶
show       sms        subscriber
```

❶ Type `<tab>` here.

At this point, you may choose `show`, and then press `<tab>` again:

Example: Use of <tab> pressed after typing show command

```
OpenBSC> show ❶
version    online-help history    network    bts        trx
timeslot   lchan      paging     paging-group logging    alarms
stats      e1_driver  e1_line    e1_timeslot subscriber statistics
sms-queue  smpp
```

❶ Type `<tab>` here.

8.3.3 The `list` command

The `list` command will give you a full list of all commands and their arguments available at the current node:

Example: Typing list at start of OsmoNITB VIEW node prompt

```
OpenBSC> list
  show version
  show online-help
  list
  exit
  help
  enable
  terminal length <0-512>
  terminal no length
  who
  show history
  show network
  show bts [<0-255>]
  show trx [<0-255>] [<0-255>]
  show timeslot [<0-255>] [<0-255>] [<0-7>]
  show lchan [<0-255>] [<0-255>] [<0-7>] [lchan_nr]
  show lchan summary [<0-255>] [<0-255>] [<0-7>] [lchan_nr]
  show paging [<0-255>]
  show paging-group <0-255> IMSI
  logging enable
  logging disable
  logging filter all (0|1)
  logging color (0|1)
  logging timestamp (0|1)
  logging print extended-timestamp (0|1)
  logging print category (0|1)
  logging set-log-mask MASK
  logging level (all|rll|cc|mm|rr|rsl|nm|mncc|pag|meas|sccp|msc|mgcp|ho|db|ref|gprs|ns| ↩
      bssgp|llc|sndcp|nat|ctrl|smpp|filter|lglobal|llapd|linp|lmux|lmi|lmib|lsms|lctrl|lgtp| ↩
      lstats) (debug|info|notice|error|fatal)
```

```
  show logging vty
  show alarms
  show stats
  show stats level (global|peer|subscriber)
  show e1_driver
  show e1_line [line_nr] [stats]
  show e1_timeslot [line_nr] [ts_nr]
  show subscriber (extension|imsi|tmsi|id) ID
  show subscriber cache
  sms send pending
  subscriber create imsi ID
  subscriber (extension|imsi|tmsi|id) ID sms sender (extension|imsi|tmsi|id) SENDER_ID send ↩
       .LINE
  subscriber (extension|imsi|tmsi|id) ID silent-sms sender (extension|imsi|tmsi|id)  ↩
      SENDER_ID send .LINE
  subscriber (extension|imsi|tmsi|id) ID silent-call start (any|tch/f|tch/any|sdcch)
  subscriber (extension|imsi|tmsi|id) ID silent-call stop
  subscriber (extension|imsi|tmsi|id) ID ussd-notify (0|1|2) .TEXT
  subscriber (extension|imsi|tmsi|id) ID update
  show statistics
  show sms-queue
  logging filter imsi IMSI
  show smpp esme
```

Tip

Remember, the list of available commands will change significantly depending on the Osmocom program you are accessing, its software version and the current node you're at. Compare the above example of the OsmoNITB *VIEW* node with the list of the OsmoNITB *TRX* config node:

Example: Typing list at start of OsmoNITB TRX config node prompt

```
OpenBSC(config-net-bts-trx)# list
  help
  list
  write terminal
  write file
  write memory
  write
  show running-config
  exit
  end
  arfcn <0-1023>
  description .TEXT
  no description
  nominal power <0-100>
  max_power_red <0-100>
  rsl e1 line E1_LINE timeslot <1-31> sub-slot (0|1|2|3|full)
  rsl e1 tei <0-63>
  rf_locked (0|1)
  timeslot <0-7>
```

9 libosmocore Logging System

In any reasonably complex software it is important to understand how to enable and configure logging in order to get a better insight into what is happening, and to be able to follow the course of action. We therefore ask the reader to bear with us while we explain how the logging subsystem works and how it is configured.

Most Osmocom Software (like `osmo-bts`, `osmo-bsc`, `osmo-nitb`, `osmo-sgsn` and many others) uses the same common logging system.

This chapter describes the architecture and configuration of this common logging system.

The logging system is composed of

- log targets (where to log),
- log categories (who is creating the log line),
- log levels (controlling the verbosity of logging), and
- log filters (filtering or suppressing certain messages).

All logging is done in human-readable ASCII-text. The logging system is configured by means of VTY commands that can either be entered interactively, or read from a configuration file at process start time.

9.1 Log categories

Each sub-system of the program in question typically logs its messages as a different category, allowing fine-grained control over which log messages you will or will not see. For example, in OsmoBSC, there are categories for the protocol layers `rsl`, `rr`, `mm`, `cc` and many others. To get a a list of categories interactively on the vty, type: `logging level ?`

9.2 Log levels

For each of the log categories (see Section 9.1), you can set an independent log level, controlling the level of verbosity. Log levels include:

fatal
Fatal messages, causing abort and/or re-start of a process. This *shouldn't happen*.

error
An actual error has occurred, its cause should be further investigated by the administrator.

notice
A noticeable event has occurred, which is not considered to be an error.

info
Some information about normal/regular system activity is provided.

debug
Verbose information about internal processing of the system, used for debugging purpose. This will log the most.

The log levels are inclusive, e.g. if you select *info*, then this really means that all events with a level of at least *info* will be logged, i.e. including events of *notice*, *error* and *fatal*.

So for example, in OsmoBSC, to set the log level of the Mobility Management category to info, you can use the following command: `log level mm info`.

There is also a special command to set all categories as a one-off to a desired log level. For example, to silence all messages but those logged as notice and above issue the command: `log level set-all notice`

Afterwards you can adjust specific categories as usual.

A similar command is `log level force-all <level>` which causes all categories to behave as if set to log level <level> until the command is reverted with `no log level force-all` after which the individually-configured log levels will again take effect. The difference between `set-all` and `force-all` is that `set-all` actually changes the individual category settings while `force-all` is a (temporary) override of those settings and does not change them.

9.3 Log printing options

The logging system has various options to change the information displayed in the log message.

log color 1
With this option each log message will log with the color of its category. The color is hard-coded and can not be changed. As with other options a *0* disables this functionality.

log timestamp 1
Includes the current time in the log message. When logging to syslog this option should not be needed, but may come in handy when debugging an issue while logging to file.

log print extended-timestamp 1
In order to debug time-critical issues this option will print a timestamp with millisecond granularity.

log print category 1
Prefix each log message with the category name.

log print category-hex 1
Prefix each log message with the category number in hex (*<000b>*).

log print level 1
Prefix each log message with the name of the log level.

log print file 1
Prefix each log message with the source file and line number. Append the keyword `last` to append the file information instead of prefixing it.

9.4 Log filters

The default behavior is to filter out everything, i.e. not to log anything. The reason is quite simple: On a busy production setup, logging all events for a given subsystem may very quickly be flooding your console before you have a chance to set a more restrictive filter.

To request no filtering, i.e. see all messages, you may use: `log filter all 1`

In addition to generic filtering, applications can implement special log filters using the same framework to filter on particular context.

For example in OsmoBSC, to only see messages relating to a particular subscriber identified by his IMSI, you may use: `log filter imsi 262020123456789`

9.5 Log targets

Each of the log targets represent certain destination for log messages. It can be configured independently by selecting levels (see Section 9.2) for categories (see Section 9.1) as well as filtering (see Section 9.4) and other options like `logging timestamp` for example.

9.5.1 Logging to the VTY

Logging messages to the interactive command-line interface (VTY) is most useful for occasional investigation by the system administrator.

Logging to the VTY is disabled by default, and needs to be enabled explicitly for each such session. This means that multiple concurrent VTY sessions each have their own logging configuration. Once you close a VTY session, the log target will be destroyed and your log settings be lost. If you re-connect to the VTY, you have to again activate and configure logging, if you wish.

To create a logging target bound to a VTY, you have to use the following command: `logging enable` This doesn't really activate the generation of any output messages yet, it merely creates and attaches a log target to the VTY session. The newly-created target still doesn't have any filter installed, i.e. *all log messages will be suppressed by default*

Next, you can configure the log levels for desired categories in your VTY session. See Section 9.1 for more details on categories and Section 9.2 for the log level details.

For example, to set the log level of the Call Control category to debug, you can use: `log level cc debug`

Finally, after having configured the levels, you still need to set the filter as it's described in Section 9.4.

Tip
If many messages are being logged to a VTY session, it may be hard to impossible to still use the same session for any commands. We therefore recommend to open a second VTY session in parallel, and use one only for logging, while the other is used for interacting with the system. Another option would be to use different log target.

To review the current vty logging configuration, you can use: `show logging vty`

9.5.2 Logging to the ring buffer

To avoid having separate VTY session just for logging output while still having immediate access to them, one can use `alarms` target. It lets you store the log messages inside the ring buffer of a given size which is available with `show alarms` command.

It's configured as follows:

```
OsmoBSC> enable
OsmoBSC# configure terminal
OsmoBSC(config)# log alarms 98
OsmoBSC(config-log)#
```

In the example above 98 is the desired size of the ring buffer (number of messages). Once it's filled, the incoming log messages will push out the oldest messages available in the buffer.

9.5.3 Logging via gsmtap

When debugging complex issues it's handy to be able to reconstruct exact chain of events. This is enabled by using GSMTAP log output where frames sent/received over the air are intersperced with the log lines. It also simplifies the bug handling as users don't have to provide separate .pcap and .log files anymore - everything will be inside self-contained packet dump.

It's configured as follows:

```
OsmoBSC> enable
OsmoBSC# configure terminal
OsmoBSC(config)# log gsmtap 192.168.2.3
OsmoBSC(config-log)#
```

The hostname/ip argument is optional: if omitted the default 127.0.0.1 will be used. The log strings inside GSMTAP are already supported by Wireshark. Capturing for `port 4729` on appropriate interface will reveal log messages including source file name and line number as well as application. This makes it easy to consolidate logs from several different network components alongside the air frames. You can also use Wireshark to quickly filter logs for a given subsystem, severity, file name etc.

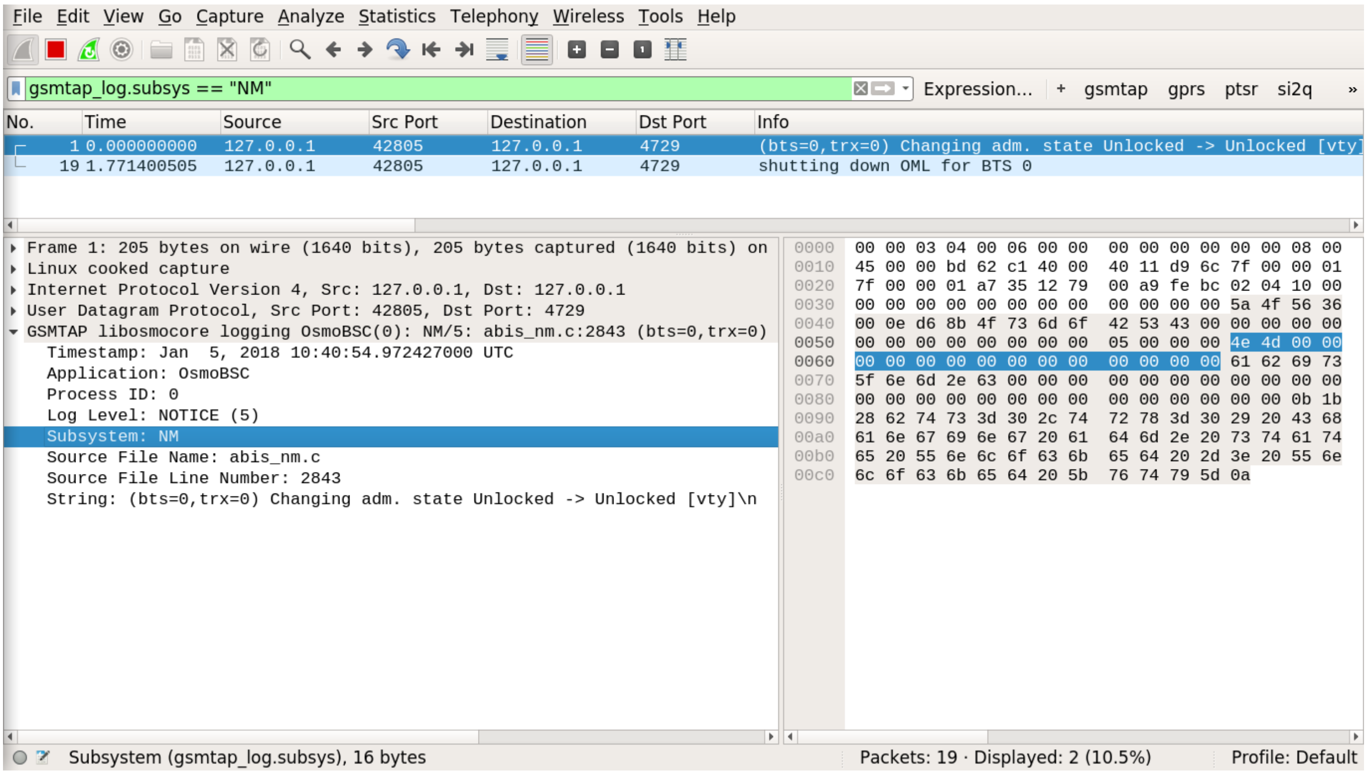


Figure 2: Wireshark with logs delivered over GSMTAP

Note: the logs are also duplicated to stderr when GSMTAP logging is configured because stderr is the default log target which is initialized automatically. To descrease stderr logging to absolute minimum, you can configure it as follows:

```
OsmoBSC> enable
OsmoBSC# configure terminal
OsmoBSC(config)# log stderr
OsmoBSC(config-log)# logging level all fatal
```

9.5.4 Logging to a file

As opposed to Logging to the VTY, logging to files is persistent and stored in the configuration file. As such, it is configured in sub-nodes below the configuration node. There can be any number of log files active, each of them having different settings regarding levels / subsystems.

To configure a new log file, enter the following sequence of commands:

```
OsmoBSC> enable
OsmoBSC# configure terminal
OsmoBSC(config)# log file /path/to/my/file
OsmoBSC(config-log)#
```

This leaves you at the config-log prompt, from where you can set the detailed configuration for this log file. The available commands at this point are identical to configuring logging on the VTY, they include `logging filter`, `logging level` as well as `logging color` and `logging timestamp`.

Tip

Don't forget to use the `copy running-config startup-config` (or its short-hand `write file`) command to make your logging configuration persistent across application re-start.

Note

libosmocore provides file close-and-reopen support by SIGHUP, as used by popular log file rotating solutions such as https://github.com/logrotate/logrotate found in most GNU/Linux distributions.

9.5.5 Logging to syslog

syslog is a standard for computer data logging maintained by the IETF. Unix-like operating systems like GNU/Linux provide several syslog compatible log daemons that receive log messages generated by application programs.

libosmocore based applications can log messages to syslog by using the syslog log target. You can configure syslog logging by issuing the following commands on the VTY:

```
OsmoBSC> enable
OsmoBSC# configure terminal
OsmoBSC(config)# log syslog daemon
OsmoBSC(config-log)#
```

This leaves you at the config-log prompt, from where you can set the detailed configuration for this log file. The available commands at this point are identical to configuring logging on the VTY, they include `logging filter`, `logging level` as well as `logging color` and `logging timestamp`.

Note

Syslog daemons will normally automatically prefix every message with a time-stamp, so you should disable the libosmocore time-stamping by issuing the `logging timestamp 0` command.

9.5.6 Logging to stderr

If you're not running the respective application as a daemon in the background, you can also use the stderr log target in order to log to the standard error file descriptor of the process.

In order to configure logging to stderr, you can use the following commands:

```
OsmoBSC> enable
OsmoBSC# configure terminal
OsmoBSC(config)# log stderr
OsmoBSC(config-log)#
```

10 Control interface

The actual protocol is described in Section 11, the variables common to all programs using it are described in Section 11.2. This section describes the CTRL interface variables specific to OsmoHLR.

All subscriber variables are available by different selectors, which are freely interchangeable:

Table 3: Subscriber selectors available on OsmoHLR's Control interface

Selector	Comment
subscriber.**by-imsi-**_123456_.*	Subscriber selector by IMSI, replace "123456" with the actual IMSI
subscriber.**by-msisdn-**_123456_.*	Subscriber selector by MSISDN
subscriber.**by-id-**_123456_.*	Subscriber selector by database ID

Each of the above selectors feature all of these control variables:

Table 4: Subscriber variables available on OsmoHLR's Control interface

Name	Access	Trap	Value	Comment
subscriber.by-*.**info**	R	No		List (short) subscriber information
subscriber.by-*.**info-aud**	R	No		List subscriber authentication tokens
subscriber.by-*.**info-all**	R	No		List both *info* and *info-aud* in one
subscriber.by-*.**cs-enabled**	RW	No	*1* or *0*	Enable/disable circuit-switched access
subscriber.by-*.**ps-enabled**	RW	No	*1* or *0*	Enable/disable packet-switched access

10.1 subscriber.by-*.info, info-aud, info-all

Query the HLR database and return current subscriber record, in multiple lines of the format

```
name<tab>value
```

To keep the reply as short as possible, some values are omitted if they are empty. These are the returned values and their presence modalities; for their meaning, see Section 6.2:

Table 5: Returned values by OsmoHLR's *info*, *info-all* and *info-aud* commands

Returned by *info-all* and	Name	Format	Presence
info	id	-9223372036854775808 .. 9223372036854775807 (usually not negative)	always
info	imsi	6 to 15 decimal digits	always
info	msisdn	1 to 15 decimal digits	when non-empty
info	nam_cs	*1* if CS is enabled, or *0*	always
info	nam_ps	*1* if PS is enabled, or *0*	always
info	vlr_number	up to 15 decimal digits	when non-empty
info	sgsn_number	up to 15 decimal digits	when non-empty
info	sgsn_address		when non-empty
info	ms_purged_cs	*1* if CS is purged, or *0*	always
info	ms_purged_ps	*1* if PS is purged, or *0*	always
info	periodic_lu_timer	0..4294967295	always
info	periodic_rau_tau_timer	0..4294967295	always
info	lmsi	8 hex digits	always
info-aud	aud2g.algo	one of *comp128v1*, *comp128v2*, *comp128v3* or *xor*	when valid 2G auth data is set
info-aud	aud2g.ki	32 hexadecimal digits	when valid 2G auth data is set
info-aud	aud3g.algo	so far always *milenage*	when valid 3G auth data is set
info-aud	aud3g.k	32 hexadecimal digits	when valid 3G auth data is set
info-aud	aud3g.op	32 hexadecimal digits	when valid 3G auth data is set, **not** when OPC is set
info-aud	aud3g.opc	32 hexadecimal digits	when valid 3G auth data is set, **not** when OP is set
info-aud	aud3g.ind_bitlen	0..28	when valid 3G auth data is set
info-aud	aud3g.sqn	0 .. 18446744073709551615	when valid 3G auth data is set

This is an example Control Interface transcript that illustrates the various *info* commands:

```
GET 1 subscriber.by-imsi-901990000000003.info
GET_REPLY 1 subscriber.by-imsi-901990000000003.info
id      3
imsi    901990000000003
msisdn  103
nam_cs  1
nam_ps  1
ms_purged_cs    0
ms_purged_ps    0
periodic_lu_timer       0
periodic_rau_tau_timer  0
lmsi    00000000

GET 2 subscriber.by-msisdn-103.info-aud
GET_REPLY 2 subscriber.by-msisdn-103.info-aud
aud2g.algo      COMP128v1
aud2g.ki        000102030405060708090a0b0c0d0e0f
aud3g.algo      MILENAGE
aud3g.k 000102030405060708090a0b0c0d0e0f
aud3g.opc       101112131415161718191a1b1c1d1e1f
aud3g.ind_bitlen        5
aud3g.sqn       0

GET 3 subscriber.by-id-3.info-all
GET_REPLY 3 subscriber.by-id-3.info-all
id      3
imsi    901990000000003
msisdn  103
nam_cs  1
nam_ps  1
ms_purged_cs    0
ms_purged_ps    0
periodic_lu_timer       0
periodic_rau_tau_timer  0
lmsi    00000000
aud2g.algo      COMP128v1
aud2g.ki        000102030405060708090a0b0c0d0e0f
aud3g.algo      MILENAGE
aud3g.k 000102030405060708090a0b0c0d0e0f
aud3g.opc       101112131415161718191a1b1c1d1e1f
aud3g.ind_bitlen        5
aud3g.sqn       0
```

10.2 subscriber.by-*.ps-enabled, cs-enabled

Disable or enable packet-/circuit-switched access for the given IMSI;

- *ps-enabled* switches access to GPRS or UMTS data services,
- *cs-enabled* switches access to voice services.

When disabled, the next time this subscriber attempts to do a Location Updating GSUP operation for the given domain (i.e. from the SGSN for *ps-enabled*, from the MSC/VLR for *cs-enabled*), it will be rejected by OsmoHLR. Currently connected GSUP clients will be notified via GSUP when a subscriber is being disabled, so that the subscriber can be dropped in case it is currently attached.

The current *ps-enabled*/*cs-enabled* status can be queried by *GET* commands, and also by looking at *nam_ps* and *nam_cs* in a *subscriber.by-*.info* response.

A value of "1" indicates that the given domain is enabled, which is the default; a value of "0" disables access.

This is an example transcript that illustrates *ps-enabled* and *cs-enabled* commands:

```
GET 1 subscriber.by-msisdn-103.info
GET_REPLY 1 subscriber.by-msisdn-103.info
id      3
imsi    901990000000003
msisdn  103
nam_cs  1
nam_ps  1
ms_purged_cs    0
ms_purged_ps    0
periodic_lu_timer       0
periodic_rau_tau_timer  0
lmsi    00000000

GET 2 subscriber.by-msisdn-103.ps-enabled
GET_REPLY 2 subscriber.by-msisdn-103.ps-enabled 1

SET 3 subscriber.by-msisdn-103.ps-enabled 0
SET_REPLY 3 subscriber.by-msisdn-103.ps-enabled OK

GET 4 subscriber.by-msisdn-103.ps-enabled
GET_REPLY 4 subscriber.by-msisdn-103.ps-enabled 0

GET 5 subscriber.by-msisdn-103.info
GET_REPLY 5 subscriber.by-msisdn-103.info
id      3
imsi    901990000000003
msisdn  103
nam_cs  1
nam_ps  0
ms_purged_cs    0
ms_purged_ps    0
periodic_lu_timer       0
periodic_rau_tau_timer  0
lmsi    00000000

SET 6 subscriber.by-msisdn-103.cs-enabled 0
SET_REPLY 6 subscriber.by-msisdn-103.cs-enabled OK

GET 7 subscriber.by-msisdn-103.cs-enabled
GET_REPLY 7 subscriber.by-msisdn-103.cs-enabled 0

GET 8 subscriber.by-msisdn-103.info
GET_REPLY 8 subscriber.by-msisdn-103.info
id      3
imsi    901990000000003
msisdn  103
nam_cs  0
nam_ps  0
ms_purged_cs    0
ms_purged_ps    0
periodic_lu_timer       0
periodic_rau_tau_timer  0
lmsi    00000000

SET 9 subscriber.by-msisdn-103.cs-enabled 1
SET_REPLY 9 subscriber.by-msisdn-103.cs-enabled OK
```

```
SET 10 subscriber.by-msisdn-103.ps-enabled 1
SET_REPLY 10 subscriber.by-msisdn-103.ps-enabled OK

GET 11 subscriber.by-msisdn-103.info
GET_REPLY 11 subscriber.by-msisdn-103.info
id      3
imsi    901990000000003
msisdn  103
nam_cs  1
nam_ps  1
ms_purged_cs    0
ms_purged_ps    0
periodic_lu_timer       0
periodic_rau_tau_timer  0
lmsi    00000000
```

11 Osmocom Control Interface

The VTY interface as described in Section 8 is aimed at human interaction with the respective Osmocom program.

Other programs **should not** use the VTY interface to interact with the Osmocom software, as parsing the textual representation is cumbersome, inefficient, and will break every time the formatting is changed by the Osmocom developers.

Instead, the *Control Interface* was introduced as a programmatic interface that can be used to interact with the respective program.

11.1 Control Interface Protocol

The control interface protocol is a mixture of binary framing with text based payload.

The protocol for the control interface is wrapped inside the IPA multiplex header with the stream identifier set to IPAC_PROTO_OSMO (0xEE).

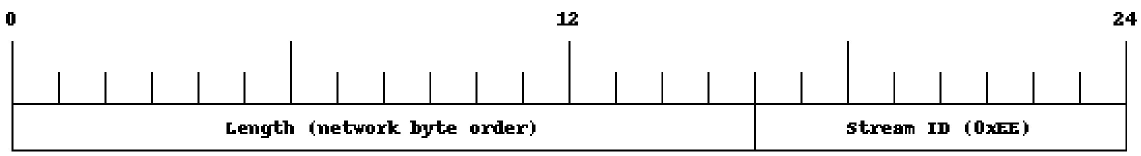


Figure 3: IPA header for control protocol

Inside the IPA header is a single byte of extension header with protocol ID 0x00 which indicates the control interface.

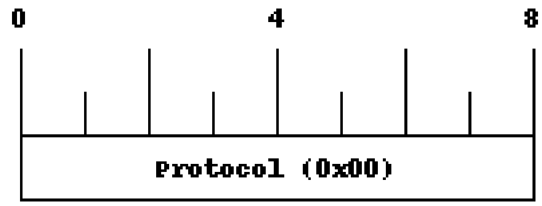


Figure 4: IPA extension header for control protocol

After the concatenation of the two above headers, the plain-text payload message starts. The format of that plain text is illustrated for each operation in the respective message sequence chart in the chapters below.

The fields specified below follow the following meaning:

<id>
A numeric identifier, uniquely identifying this particular operation. `0` is not allowed. It will be echoed back in any response to a particular request.

<var>
The name of the variable / field affected by the GET / SET / TRAP operation. Which variables/fields are available is dependent on the specific application under control.

<val>
The value of the variable / field

<reason>
A text formatted, human-readable reason why the operation resulted in an error.

11.1.1 GET operation

The GET operation is performed by an external application to get a certain value from inside the Osmocom application.

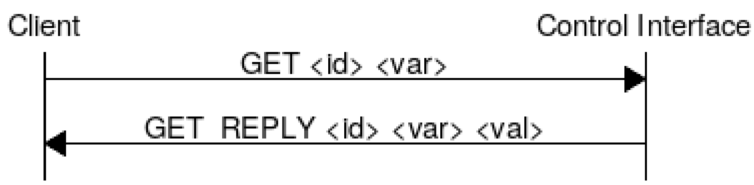


Figure 5: Control Interface GET operation (successful outcome)

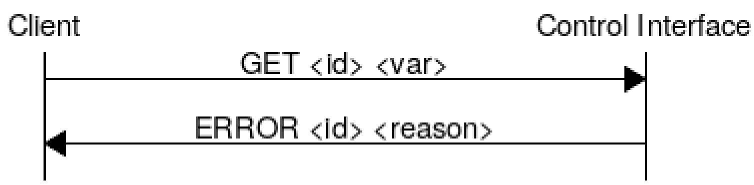


Figure 6: Control Interface GET operation (unsuccessful outcome)

11.1.2 SET operation

The SET operation is performed by an external application to set a value inside the Osmocom application.

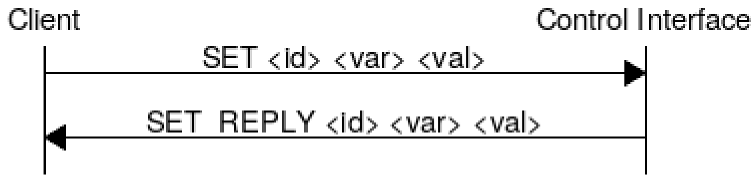


Figure 7: Control Interface SET operation (successful outcome)

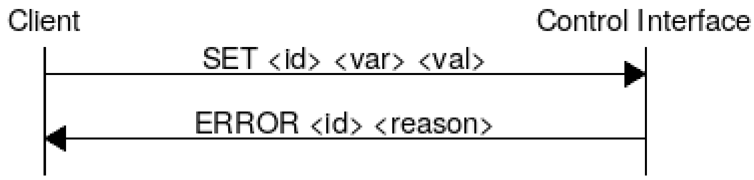


Figure 8: Control Interface SET operation (unsuccessful outcome)

11.1.3 TRAP operation

The program can at any time issue a trap. The term is used in the spirit of SNMP.

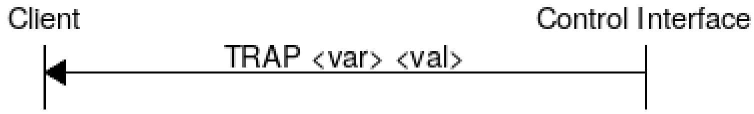


Figure 9: Control Interface TRAP operation

11.2 Common variables

There are several variables which are common to all the programs using control interface. They are described in the following table.

Table 6: Variables available over control interface

Name	Access	Value	Comment
counter.*	RO		Get counter value.
rate_ctr.*	RO		Get list of rate counter groups.
rate_ctr.IN.GN.GI.name	RO		Get value for interval IN of rate counter name which belong to group named GN with index GI.

Those read-only variables allow to get value of arbitrary counter using its name.

For example "`rate_ctr.per_hour.bsc.0.handover:timeout`" is the number of handover timeouts per hour.

Of course for that to work the program in question have to register corresponding counter names and groups using libosmocore functions.

In the example above, "`bsc`" is the rate counter group name and "`0`" is its index. It is possible to obtain all the rate counters in a given group by requesting "`rate_ctr.per_sec.bsc.*`" variable.

The list of available groups can be obtained by requesting "`rate_ctr.*`" variable.

The rate counter group name have to be prefixed with interval specification which can be any of "**per_sec**", "**per_min**", "**per_hour**", "**per_day**" or "**abs**" for absolute value.

The old-style counters available via "`counter.*`" variables are superceeded by "`rate_ctr.abs`" so its use is discouraged. There might still be some applications not yet converted to rate_ctr.

11.3 Control Interface python examples

In the `osmo-python-tests` repository, there is an example python script called `scripts/osmo_ctrl.py` which implements the Osmocom control interface protocol.

You can use this tool either stand-alone to perform control interface operations against an Osmocom program, or you can use it as a reference for developing your own python software talking to the control interface.

Another implementation is in `scripts/osmo_rate_ctr2csv.py` which will retrieve performance counters for a given Osmocom program and output it in csv format. This can be used to periodically (using systemd timer for example) retrieve data to build KPI and evaluate how it changes over time.

Internally it uses "`rate_ctr.*`" variable described in [?] to get the list of counter groups and than request all the counters in each group. Applications interested in individual metrics can request it directly using `rate_ctr2csv.py` as an example.

11.3.1 Getting rate counters

Example: Use rate_ctr2csv.py to get rate counters from OsmoBSC

```
$ ./scripts/osmo_rate_ctr2csv.py --header
Connecting to localhost:4249...
Getting rate counter groups info...
"group","counter","absolute","second","minute","hour","day"
"e1inp.0","hdlc:abort","0","0","0","0","0"
"e1inp.0","hdlc:bad_fcs","0","0","0","0","0"
"e1inp.0","hdlc:overrun","0","0","0","0","0"
"e1inp.0","alarm","0","0","0","0","0"
"e1inp.0","removed","0","0","0","0","0"
"bsc.0","chreq:total","0","0","0","0","0"
"bsc.0","chreq:no_channel","0","0","0","0","0"
...
"msc.0","call:active","0","0","0","0","0"
"msc.0","call:complete","0","0","0","0","0"
"msc.0","call:incomplete","0","0","0","0","0"
Completed: 44 counters from 3 groups received.
```

11.3.2 Setting a value

Example: Use osmo_ctrl.py to set the short network name of OsmoBSC

```
$ ./osmo_ctrl.py -d localhost -s short-name 32C3
Got message: SET_REPLY 1 short-name 32C3
```

11.3.3 Getting a value

Example: Use osmo_ctrl.py to get the mnc of OsmoBSC

```
$ ./osmo_ctrl.py -d localhost -g mnc
Got message: GET_REPLY 1 mnc 262
```

11.3.4 Listening for traps

You can use `osmo_ctrl.py` to listen for traps the following way:

Example: Using osmo_ctrl.py to listen for traps:

```
$ ./osmo_ctrl.py -d localhost -m
❶
```

❶ the command will not return and wait for any TRAP messages to arrive

12 Generic Subscriber Update Protocol

12.1 General

This chapter describes the remote protocol that is used by OsmoSGSN and OsmoMSC to update and manage the local subscriber list in OsmoHLR. Functionally, it resembles the interface between the SGSN/VLR on the one hand side, and HLR/AUC on the other side.

For more information, see the specification of the Gr interface (3GPP TS 03.60).

Traditionally, the GSM MAP (Mobile Application Part) protocol is used for this purpose, running on top of a full telecom signalling protocol stack of MTP2/MTP3/SCCP/TCAP, or any of the SIGTRAN alternatives.

In order to avoid many of the complexities of MAP, which are difficult to implement in the plain C language environment of the Osmocom cellular network elements like the SGSN, we introduce the GSUP protocol.

The GSUP protocol and the messages are designed after the corresponding MAP messages (see 3GPP TS 09.02) with the following main differences:

- The encoding uses TLV structures instead of ASN.1 BER
- Segmentation is not used, i.e. we rely on the fact that the underlying transport protocol can transport signalling messages of any size.

12.2 Connection

The protocol expects that a reliable, ordered, packet boundaries preserving connection is used (e.g. IPA over TCP). The remote peer is either a service that understands the protocol natively or a wrapper service that maps the messages to/from real MAP messages that can be used to directly communicate with an HLR.

12.3 Using IPA

By default, the following identifiers should be used:

- IPA Stream ID: 0xEE (OSMO)
- IPA OSMO protocol extension: 0x05

For more information about the IPA multiplex, please see the *OsmoBTS Abis/IP Specification*.

12.4 Procedures

12.4.1 Authentication management

The SGSN or VLR sends a SEND_AUTHENTICATION_INFO_REQ message containing the MS's IMSI to the peer. On errors, especially if authentication info is not available for that IMSI, the peer returns a SEND_AUTHENTICATION_INFO_ERR message. Otherwise the peer returns a SEND_AUTHENTICATION_INFO_RES message. If this message contains at least one authentication tuple, the SGSN or VLR replaces all tuples that are assigned to the subscriber. If the message doesn't contain any tuple the SGSN or VLR may reject the Attach Request. (see 3GPP TS 09.02, 25.5.6)

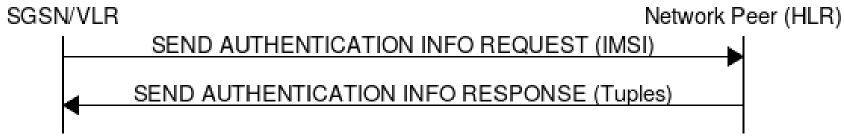


Figure 10: Send Authentication Info (Normal Case)

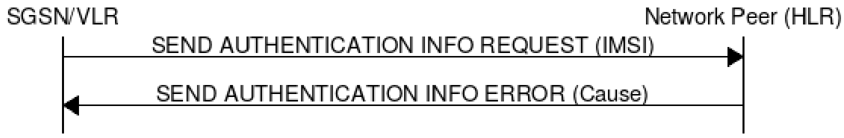


Figure 11: Send Authentication Info (Erroneous Case)

12.4.2 Reporting of Authentication Failure

Using this procedure, the SGSN or VLR reports authentication failures to the HLR.

Figure 12: Authentication Failure Report (Normal Case)

12.4.3 Location Updating

The SGSN or VLR sends a UPDATE_LOCATION_REQ to the peer. If the request is denied by the network, the peer returns an UPDATE_LOCATION_ERR message to the SGSN or VLR. Otherwise the peer returns an UPDATE_LOCATION_RES message containing all information fields that shall be inserted into the subscriber record. If the *PDP info complete* information element is set in the message, the SGSN or VLR clears existing PDP information fields in the subscriber record first. (see 3GPP TS 09.02, 19.1.1.8)

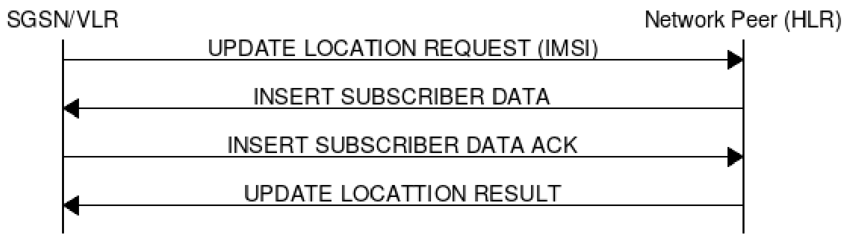


Figure 13: Update Location (Normal Case)

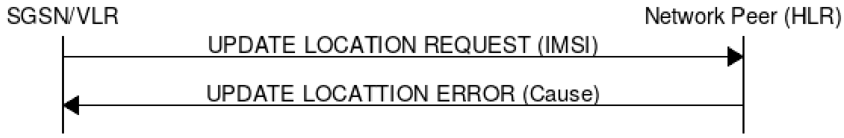


Figure 14: Update Location (Error Case)

12.4.4 Location Cancellation

Using the Location Cancellation procedure, the Network Peer (HLR) can request the SGSN or VLR to remove a subscriber record.

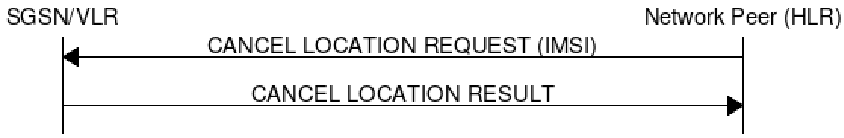


Figure 15: Cancel Location (Normal Case)

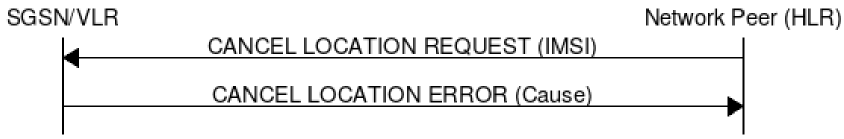


Figure 16: Cancel Location (Error Case)

12.4.5 Purge MS

Using the Purge MS procedure, the SGSN or VLR can request purging of MS related state from a previous SGSN or VLR during an inter-SGSN / inter-MSC location update.

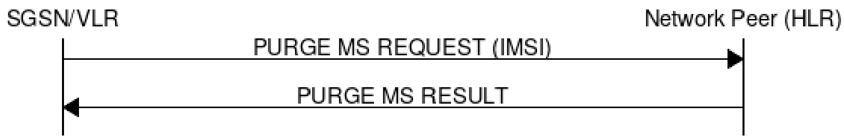


Figure 17: Purge MS (Normal Case)

12.4.6 Delete Subscriber Data

Using the Delete Subscriber Data procedure, the Peer (HLR) can remove some of the subscriber data from the SGSN or VLR. This is used in case the subscription details (e.g. PDP Contexts / APNs) change while the subscriber is registered to that SGSN VLR.

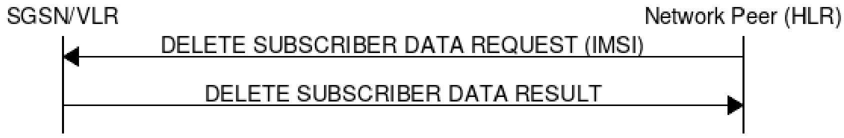


Figure 18: Delete Subscriber Data (Normal Case)

12.5 Message Format

12.5.1 General

Every message is based on the following message format

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10

If a numeric range is indicated in the *presence* column, multiple information elements with the same tag may be used in sequence. The information elements shall be sent in the given order. Nevertheless after the generic part the receiver shall be able to received them in any order. Unknown IE shall be ignored.

12.5.2 Send Authentication Info Request

Direction: SGSN / VLR ⇒ HLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
28	CN Domain	Section 12.6.15	O	TLV	3
26	AUTS	Section 12.6.13	C	TLV	18
20	RAND	Section 12.6.7	C	TLV	18

The conditional *AUTS* and *RAND* IEs are both present in case the SIM (via UE) requests an UMTS AKA re-synchronization procedure. Eiter both optional IEs are present, or none of them.

12.5.3 Send Authentication Info Error

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
02	Cause	Section 12.6.25	M	TLV	3

12.5.4 Send Authentication Info Response

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10

IEI	IE	Type	Presence	Format	Length
03	Auth Tuple	Section 12.6.6	0-5	TLV	36

12.5.5 Authentication Failure Report

Direction: SGSN / VLR ⇒ HLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
28	CN Domain	Section 12.6.15	O	TLV	3

12.5.6 Update Location Request

Direction: SGSN / VLR ⇒ HLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
28	CN Domain	Section 12.6.15	O	TLV	3

12.5.7 Update Location Error

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
02	Cause	Section 12.6.25	M	TLV	3

12.5.8 Update Location Result

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
08	MSISDN	Section 12.6.20	O	TLV	0-9
09	HLR Number	Section 12.6.24	O	TLV	0-9
04	PDP info complete	Section 12.6.18	O	TLV	2
05	PDP info	Section 12.6.3	1-10	TLV	

If the PDP info complete IE is present, the old PDP info list shall be cleared.

12.5.9 Location Cancellation Request

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
28	CN Domain	Section 12.6.15	O	TLV	3
06	Cancellation type	Section 12.6.16	O	TLV	3

12.5.10 Location Cancellation Result

Direction: SGSN / VLR ⇒ HLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
28	CN Domain	Section 12.6.15	O	TLV	3

12.5.11 Purge MS Request

Direction: SGSN / VLR ⇒ HLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
28	CN Domain	Section 12.6.15	O	TLV	3
09	HLR Number	Section 12.6.24	M	TLV	0-9

12.5.12 Purge MS Error

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
02	Cause	Section 12.6.25	M	TLV	3

12.5.13 Purge MS Result

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
07	Freeze P-TMSI	Section 12.6.18	M	TLV	2

12.5.14 Insert Subscriber Data Request

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
28	CN Domain	Section 12.6.15	O	TLV	3
08	MSISDN	Section 12.6.20	O	TLV	0-9
09	HLR Number	Section 12.6.24	O	TLV	0-9
04	PDP info complete	Section 12.6.18	M	TLV	2
05	PDP info	Section 12.6.3	0-10	TLV	
14	PDP-Charging Characteristics	Section 12.6.23	O	TLV	4

If the PDP info complete IE is present, the old PDP info list shall be cleared.

12.5.15 Insert Subscriber Data Error

Direction: SGSN / VLR ⇒ HLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
02	Cause	Section 12.6.25	M	TLV	3

12.5.16 Insert Subscriber Data Result

Direction: SGSN / VLR ⇒ HLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10

12.5.17 Delete Subscriber Data Request

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
28	CN Domain	Section 12.6.15	O	TLV	3
10	PDP context id	Section 12.6.3 (no conditional IE)	0-10	TLV	

12.5.18 Delete Subscriber Data Error

Direction: SGSN / VLR ⇒ HLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
02	Cause	Section 12.6.25	M	TLV	3

12.5.19 Delete Subscriber Data Result

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10

12.5.20 Process Supplementary Service Request

Direction: bidirectional

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
30	Session ID	Section 12.7.1	M	TLV	6
31	Session State	Section 12.7.2	M	TLV	3

IEI	IE	Type	Presence	Format	Length
35	Supplementary Service Info	Section 12.6.26	O	TLV	2-...

This message is used in both directions in case of USSD, because it is not known is it request or response without parsing the GSM 04.80 payload.

12.5.21 Process Supplementary Service Error

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
30	Session ID	Section 12.7.1	M	TLV	6
31	Session State	Section 12.7.2	M	TLV	3
02	Cause	Section 12.6.25	M	TLV	3

12.5.22 Process Supplementary Service Response

Direction: HLR ⇒ SGSN / VLR

IEI	IE	Type	Presence	Format	Length
	Message Type	Section 12.6.1	M	V	1
01	IMSI	Section 12.6.19	M	TLV	2-10
30	Session ID	Section 12.7.1	M	TLV	6
31	Session State	Section 12.7.2	M	TLV	3
35	Supplementary Service Info	Section 12.6.26	O	TLV	2-...

The purpose of this message is not clear yet. Probably, it can be used to notify the MSC that a structured supplementary service is successfully activated or deactivated, etc.

12.6 Information Elements

12.6.1 Message Type

Type	Description
0x04	Update Location Request
0x05	Update Location Error
0x06	Update Location Result
0x08	Send Auth Info Request
0x09	Send Auth Info Error
0x0a	Send Auth Info Result
0x0b	Authentication Failure Report
0x0c	Purge MS Request
0x0d	Purge MS Error
0x0e	Purge MS Result
0x10	Insert Subscriber Data Request
0x11	Insert Subscriber Data Error
0x12	Insert Subscriber Data Result
0x14	Delete Subscriber Data Request
0x15	Delete Subscriber Data Error

Type	Description
0x16	Delete Subscriber Data Result
0x1c	Location Cancellation Request
0x1d	Location Cancellation Error
0x1e	Location Cancellation Result
0x20	Supplementary Service Request
0x21	Supplementary Service Error
0x22	Supplementary Service Result

12.6.2 IP Address

The value part is encoded like in the Packet data protocol address IE defined in 3GPP TS 04.08, Chapter 10.5.6.4. PDP type organization must be set to *IETF allocated address*.

12.6.3 PDP Info

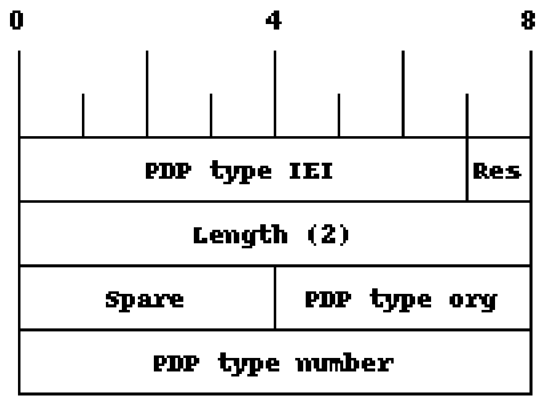
This is a container for information elements describing a single PDP.

IEI	IE	Type	Presence	Format	Length
	PDP Info IEI	Section 12.6.17	M	V	1
	Length of PDP Info IE		M	V	1
10	PDP Context ID	Section 12.6.5	C	TLV	3
11	PDP Type	Section 12.6.4	C	TLV	4
12	Access Point Name	Section 12.6.21	C	TLV	3-102
13	Quality of Service	Section 12.6.22	O	TLV	1-20
14	PDP-Charging Characteristics	Section 12.6.23	O	TLV	4

The conditional IE are mandantory unless mentioned otherwise.

12.6.4 PDP Type

The PDP type value consists of 2 octets that are encoded like octet 4-5 of the End User Address defined in 3GPP TS 09.60, 7.9.18.



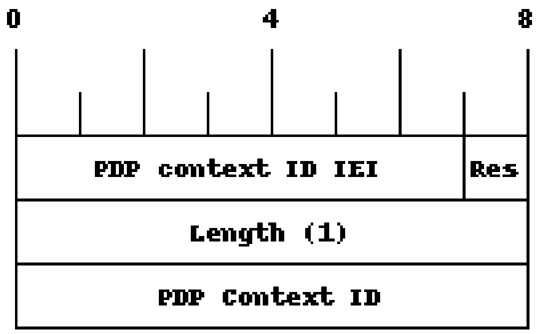
The spare bits are left undefined. While 09.60 defines them as *1 1 1 1*, there are MAP traces where these bits are set to *0 0 0 0*. So the receiver shall ignore these bits.

Examples:

- IPv4: PDP type org: 1 (IETF), PDP type number: 0x21
- IPv6: PDP type org: 1 (IETF), PDP type number: 0x57

12.6.5 PDP Context ID

The PDP type context ID IE consists of a single integer byte wrapped in a TLV.



12.6.6 Auth tuple

This is a container for information elements describing a single authentication tuple.

IEI	IE	Type	Presence	Format	Length
	Auth Tuple IEI	Section 12.6.17	M	V	1
	Length of Auth Tuple IE		M	V	1
20	RAND	Section 12.6.7	M	TLV	18
21	SRES	Section 12.6.8	M	TLV	6
22	Kc	Section 12.6.9	M	TLV	10
23	IK	Section 12.6.10	C	TLV	18
24	CK	Section 12.6.11	C	TLV	18
25	AUTN	Section 12.6.12	C	TLV	18
27	RES	Section 12.6.14	C	TLV	2-18

The conditional IEs *IK*, *CK*, *AUTN* and *RES* are onl present in case the subscriber supports UMTS AKA.

12.6.7 RAND

The 16-byte Random Challenge of the GSM Authentication Algorithm.

12.6.8 SRES

The 4-byte Authentication Result of the GSM Authentication Algorithm.

12.6.9 Kc

The 8-byte Encryption Key of the GSM Authentication and Key Agreemnt Algorithm.

12.6.10 IK

The 16-byte Integrity Protection Key generated by the UMTS Authentication and Key Agreement Algorithm.

12.6.11 CK

The 16-byte Ciphering Key generated by the UMTS Authentication and Key Agreement Algorithm.

12.6.12 AUTN

The 16-byte Authentication Nonce sent from network to USIM in the UMTS Authentication and Key Agreement Algorithm.

12.6.13 AUTS

The 14-byte Authentication Synchronization Nonce generated by the USIM in case the UMTS Authentication and Key Agreement Algorithm needs to re-synchronize the sequence counters between AUC and USIM.

12.6.14 RES

The (variable length, but typically 16 byte) Authentication Result generated by the USIM in the UMTS Authentication and Key Agreement Algorithm.

12.6.15 CN Domain

This single-byte information element indicates the Core Network Domain, i.e. if the message is related to Circuit Switched or Packet Switched services.

For backwards compatibility reasons, if no CN Domain IE is present within a request, the PS Domain is assumed.

Table 7: CN Domain Number

Type	Description
0x01	PS Domain
0x02	CS Domain

12.6.16 Cancellation Type

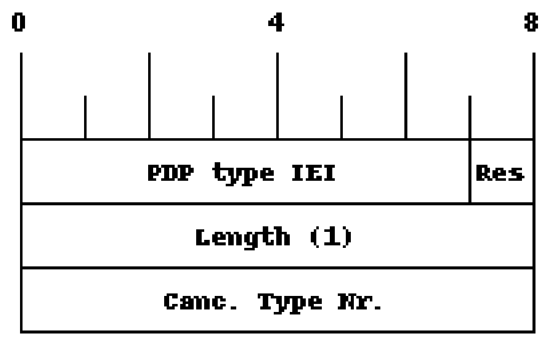


Table 8: Cancellation Type Number

Number	Description
0x00	Update Procedure
0x01	Subscription Withdrawn

12.6.17 IE Identifier (informational)

These are the standard values for the IEI. See the message definitions for the IEI that shall be used for the encoding.

Table 9: GSUP IE Identifiers

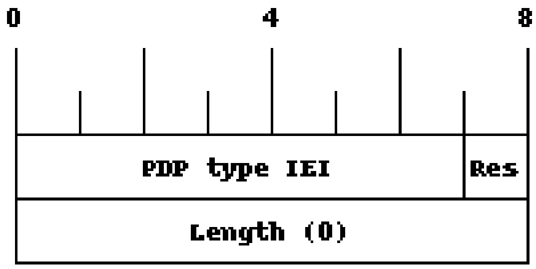
IEI	Info Element	Type / Encoding
0x01	IMSI	Mobile Identity, 3GPP TS 04.08 Ch. 10.5.1.4
0x02	Cause	Section 12.6.25
0x03	Auth Tuple	Section 12.6.6
0x04	PDP Info Compl	Section 12.6.18
0x05	PDP Info	Section 12.6.3
0x06	Cancel Type	Section 12.6.16
0x07	Freeze P-TMSI	Section 12.6.18
0x08	MSISDN	ISDN-AddressString/octet, Section 12.6.20
0x09	HLR Number	Section 12.6.24
0x10	PDP Context ID	Section 12.6.5
0x11	PDP Type	Section 12.6.4
0x12	Access Point Name	Section 12.6.21
0x13	QoS	Section 12.6.22
0x14	PDP-Charging Characteristics	Section 12.6.23
0x20	RAND	Section 12.6.7
0x21	SRES	Section 12.6.8
0x22	Kc	Section 12.6.9
0x23	IK	Section 12.6.10
0x24	CK	Section 12.6.11
0x25	AUTN	Section 12.6.12

Table 9: (continued)

IEI	Info Element	Type / Encoding
0x26	AUTS	Section 12.6.13
0x27	RES	Section 12.6.14
0x28	CN Domain	Section 12.6.15
0x30	Session ID	Section 12.7.1
0x31	Session State	Section 12.7.2
0x35	Supplementary Service Info	Section 12.6.26

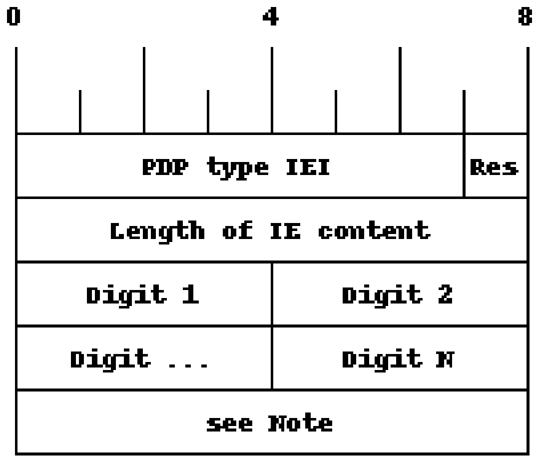
12.6.18 Empty field

This is used for flags, if and only if this IE is present, the flag is set. The semantics depend on the IEI and the context.



12.6.19 IMSI

The IMSI is encoded like in octet 4-N of the Called Party BCD Number defined in 3GPP TS 04.08, 10.5.4.7.

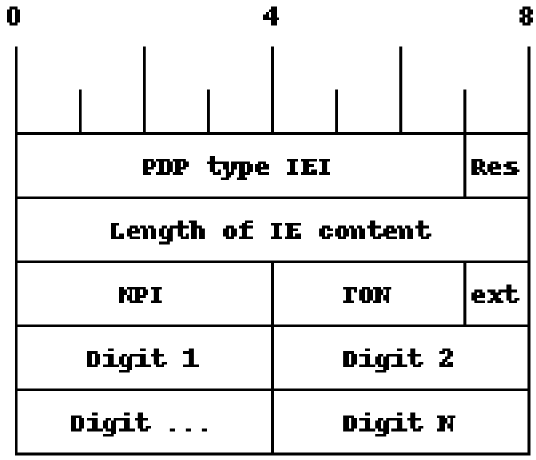


Note

Either *1 1 1 1 | Number digit N* (N odd) or *Number digit N | Number digit N-1* (N even), where N is the number of digits.

12.6.20 ISDN-AddressString / MSISDN / Called Party BCD Number

The MSISDN is encoded as an ISDN-AddressString in 3GPP TS 09.02 and Called Party BCD Number in 3GPP TS 04.08. It will be stored by the SGSN or VLR and then passed as is to the GGSN during the activation of the primary PDP Context.

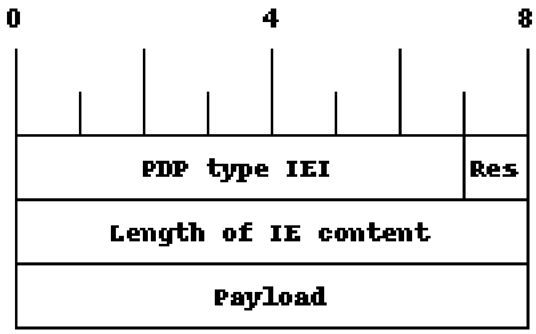


12.6.21 Access Point Name

This encodes the Access Point Name of a PDP Context. The encoding is defined in 3GPP TS 23.003.

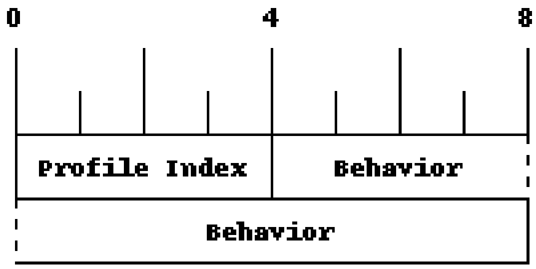
12.6.22 Quality of Service Subscribed Service

This encodes the subscribed QoS of a subscriber. It will be used by the SGSN during the PDP Context activation. If the length of the QoS data is 3 (three) octets it is assumed that these are octets 3-5 of the TS 3GPP TS 24.008 Quality of Service Octets. If it is more than three then then it is assumed that the first octet is the Allocation/Retention Priority and the reset are encoded as octets 3-N of 24.008.



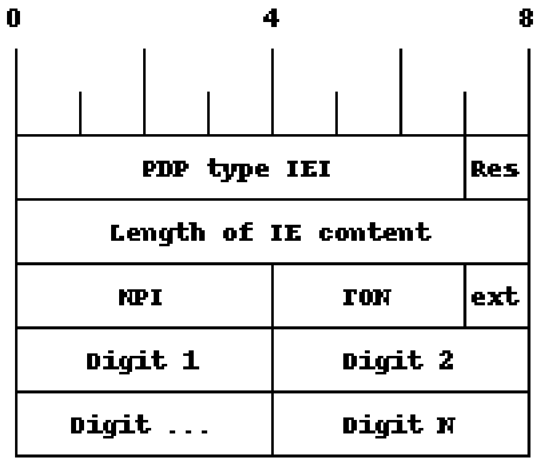
12.6.23 PDP-Charging Characteristics

This encodes the ChargingCharacteristics of 3GPP TS 32.215. A HLR may send this as part of the InsertSubscriberData or within a single PDP context definition. If the HLR supplies this information it must be used by the SGSN or VLR when activating a PDP context.



12.6.24 HLR Number encoded as 3GPP TS 09.02 ISDN-AddressString

The HLR Number is encoded as an ISDN-AddressString in 3GPP TS 09.02. It will be stored by the SGSN or VLR can be used by the CDR module to keep a record.



12.6.25 Cause

This IE shall be encoded according to the *GMM Cause* as described in Chapter 10.5.5.14 of 3GPP TS 04.08.

12.6.26 Supplementary Service Info

This IE shall be used together with both Section 12.7.2 and Section 12.7.1 IEs. It is used to carry the payload of Supplementary Services encoded according to GSM TS 04.80.

12.7 Session (transaction) management

Unlike TCAP/MAP, GSUP is just a transport layer without the dialogue/context. All communication is usually happening over a single connection. In order to fill this gap, there is a few optional IEs, which allow both communication sides to establish and terminate TCAP-like transactions over GSUP.

12.7.1 Session ID

This auxiliary IE shall be used together with Section 12.7.2. The purpose of this IE is to identify a particular transaction using the 4-byte unique identifier.

12.7.2 Session State

This auxiliary IE shall be used together with Section 12.7.1. The purpose of this IE is to indicate a state of a particular transacrion, i.e. initiate, continue or terminate it.

Table 10: Session state

State	TCAP alternative	Description
0x00	Undefined	Used when session management is not required
0x01	BEGIN	Used to initiate a new session
0x02	CONTINUE	Used to continue an existing session
0x03	END	Used to terminate an existing session

13 Glossary

2FF
2nd Generation Form Factor; the so-called plug-in SIM form factor

3FF
3rd Generation Form Factor; the so-called microSIM form factor

3GPP
3rd Generation Partnership Project

4FF
4th Generation Form Factor; the so-called nanoSIM form factor

A Interface
Interface between BTS and BSC, traditionally over E1 (*3GPP TS 48.008* [3gpp-ts-48-008])

A3/A8
Algorithm 3 and 8; Authentication and key generation algorithm in GSM and GPRS, typically COMP128v1/v2/v3 or MILENAGE are typically used

A5
Algorithm 5; Air-interface encryption of GSM; currently only A5/0 (no encryption), A5/1 and A5/3 are in use

Abis Interface
Interface between BTS and BSC, traditionally over E1 (*3GPP TS 48.058* [3gpp-ts-48-058] and *3GPP TS 52.021* [3gpp-ts-52-021])

ACC
Access Control Class; every BTS broadcasts a bit-mask of permitted ACC, and only subscribers with a SIM of matching ACC are permitted to use that BTS

AGCH
Access Grant Channel on Um interface; used to assign a dedicated channel in response to RACH request

AGPL
GNU Affero General Public License, a copyleft-style Free Software License

ARFCN
Absolute Radio Frequency Channel Number; specifies a tuple of uplink and downlink frequencies

AUC
Authentication Center; central database of authentication key material for each subscriber

BCCH
Broadcast Control Channel on Um interface; used to broadcast information about Cell and its neighbors

BCC
Base Station Color Code; short identifier of BTS, lower part of BSIC

BTS
Base Transceiver Station

BSC
Base Station Controller

BSIC
Base Station Identity Code; 16bit identifier of BTS within location area

BSSGP
Base Station Subsystem Gateway Protocol (*3GPP TS 48.018* [3gpp-ts-48-018])

BVCI
BSSGP Virtual Circuit Identifier

CBCH
Cell Broadcast Channel; used to transmit Cell Broadcast SMS (SMS-CB)

CC
Call Control; Part of the GSM Layer 3 Protocol

CCCH
Common Control Channel on Um interface; consists of RACH (uplink), BCCH, PCH, AGCH (all downlink)

Cell
A cell in a cellular network, served by a BTS

CEPT
Conférence européenne des administrations des postes et des télécommunications; European Conference of Postal and Telecommunications Administrations.

CGI
Cell Global Identifier comprised of MCC, MNC, LAC and BSIC

dB
deci-Bel; relative logarithmic unit

dBm
deci-Bel (milliwatt); unit of measurement for signal strength of radio signals

DHCP
Dynamic Host Configuration Protocol (*IETF RFC 2131* [ietf-rfc2131]

downlink
Direction of messages / signals from the network core towards the mobile phone

DSP
Digital Signal Processor

dvnixload
Tool to program UBL and the Bootloader on a sysmoBTS

EDGE
Enhanced Data rates for GPRS Evolution; Higher-speed improvement of GPRS; introduces 8PSK

EGPRS
Enhanced GPRS; the part of EDGE relating to GPRS services

ESME
External SMS Entity; an external application interfacing with a SMSC over SMPP

ETSI
European Telecommunications Standardization Institute

FPGA
Field Programmable Gate Array; programmable digital logic hardware

Gb
Interface between PCU and SGSN in GPRS/EDGE network; uses NS, BSSGP, LLC

GERAN
GPRS/EDGE Radio Access Network

GFDL
GNU Free Documentation License; a copyleft-style Documentation License

GGSN
GPRS Gateway Support Node; gateway between GPRS and external (IP) network

GMSK
Gaussian Minimum Shift Keying; modulation used for GSM and GPRS

GPL
GNU General Public License, a copyleft-style Free Software License

Gp
Gp interface between SGSN and GGSN; uses GTP protocol

GPS
Global Positioning System; provides a highly accurate clock reference besides the global position

GSM
Global System for Mobile Communications. ETSI/3GPP Standard of a 2G digital cellular network

GSMTAP
GSM tap; pseudo standard for encapsulating GSM protocol layers over UDP/IP for analysis

GT
Global Title; an address in SCCP

GTP
GPRS Tunnel Protocol; used between SGSN and GGSN

HLR
Home Location Register; central subscriber database of a GSM network

HPLMN
Home PLMN; the network that has issued the subscriber SIM and has his record in HLR

IE
Information Element

IMEI
International Mobile Equipment Identity; unique identifier for the mobile phone

IMSI
International Mobile Subscriber Identity; 15-digit unique identifier for the subscriber/SIM; starts with MCC/MNC of issuing operator

IP
Internet Protocol (*IETF RFC 791* [?])

IPA
ip.access GSM over IP protocol; used to multiplex a single TCP connection

LAC
Location Area Code; 16bit identifier of Location Area within network

LAPD
Link Access Protocol, D-Channel (*ITU-T Q.921* [itu-t-q921])

LAPDm
Link Access Protocol Mobile (*3GPP TS 44.006* [3gpp-ts-44-006])

LLC
Logical Link Control; GPRS protocol between MS and SGSN (*3GPP TS 44.064* [3gpp-ts-44-064])

Location Area
Location Area; a geographic area containing multiple BTS

M2PA
MTP2 Peer-to-Peer Adaptation; a SIGTRAN Variant (*RFC 4165* [ietf-rfc4165])

M2UA
MTP2 User Adaptation; a SIGTRAN Variant (*RFC 3331* [ietf-rfc3331])

M3UA
MTP3 User Adaptation; a SIGTRAN Variant (*RFC 4666* [ietf-rfc4666])

MCC
Mobile Country Code; unique identifier of a country, e.g. 262 for Germany

MFF
Machine-to-Machine Form Factor; a SIM chip package that is soldered permanently onto M2M device circuit boards.

MGW
Media Gateway

MM
Mobility Management; part of the GSM Layer 3 Protocol

MNC
Mobile Network Code; identifies network within a country; assigned by national regulator

MNO
Mobile Network Operator; operator with physical radio network under his MCC/MNC

MS
Mobile Station; a mobile phone / GSM Modem

MSC
Mobile Switching Center; network element in the circuit-switched core network

MSISDN
Mobile Subscriber ISDN Number; telephone number of the subscriber

MTP
Message Transfer Part; SS7 signaling protocol (*ITU-T Q.701* [itu-t-q701])

MVNO
Mobile Virtual Network Operator; Operator without physical radio network

NCC
Network Color Code; assigned by national regulator

NITB
Network In The Box; combines functionality traditionally provided by BSC, MSC, VLR, HLR, SMSC functions; see OsmoNITB

NSEI
NS Entity Identifier

NVCI
NS Virtual Circuit Identifier

NWL
Network Listen; ability of some BTS to receive downlink from other BTSs

NS
Network Service; protocol on Gb interface (*3GPP TS 48.016* [3gpp-ts-48-016])

OCXO
Oven Controlled Crystal Oscillator; very high precision oscillator, superior to a VCTCXO

OML
Operation & Maintenance Link (ETSI/*3GPP TS 52.021* [3gpp-ts-52-021])

OpenBSC
Open Source implementation of GSM network elements, specifically OsmoBSC, OsmoNITB, OsmoSGSN

OpenGGSN
Open Source implementation of a GPRS Packet Control Unit

OpenVPN
Open-Source Virtual Private Network; software employed to establish encrypted private networks over untrusted public networks

Osmocom
Open Source MObile COMmunications; collaborative community for implementing communications protocols and systems, including GSM, GPRS, TETRA, DECT, GMR and others

OsmoBSC
Open Source implementation of a GSM Base Station Controller

OsmoNITB
Open Source implementation of a GSM Network In The Box, combines functionality traditionally provided by BSC, MSC, VLR, HLR, AUC, SMSC

OsmoSGSN
Open Source implementation of a Serving GPRS Support Node

OsmoPCU
Open Source implementation of a GPRS Packet Control Unit

OTA
Over-The-Air; Capability of operators to remotely reconfigure/reprogram ISM/USIM cards

PC
Point Code; an address in MTP

PCH
Paging Channel on downlink Um interface; used by network to page an MS

PCU
Packet Control Unit; used to manage Layer 2 of the GPRS radio interface

PDCH
Packet Data Channel on Um interface; used for GPRS/EDGE signalling + user data

PIN
Personal Identification Number; a number by which the user authenticates to a SIM/USIM or other smart card

PLMN
Public Land Mobile Network; specification language for a single GSM network

PUK
PIN Unblocking Code; used to unblock a blocked PIN (after too many wrong PIN attempts)

RAC
Routing Area Code; 16bit identifier for a Routing Area within a Location Area

RACH
Random Access Channel on uplink Um interface; used by MS to request establishment of a dedicated channel

RAM
Remote Application Management; Ability to remotely manage (install, remove) Java Applications on SIM/USIM Card

RF
Radio Frequency

RFM
Remote File Management; Ability to remotely manage (write, read) files on a SIM/USIM card

Roaming
Procedure in which a subscriber of one network is using the radio network of another network, often in different countries; in some countries national roaming exists

Routing Area
Routing Area; GPRS specific sub-division of Location Area

RR
Radio Resources; Part of the GSM Layer 3 Protocol

RSL
Radio Signalling Link (*3GPP TS 48.058* [3gpp-ts-48-058])

RTP
Real-Time Transport Protocol (*IETF RFC 3550* [ietf-rfc3550]); Used to transport audio/video streams over UDP/IP

SACCH
Slow Associate Control Channel on Um interface; bundled to a TCH or SDCCH, used for signalling in parallel to active dedicated channel

SCCP
Signaling Connection Control Part; SS7 signaling protocol (*ITU-T Q.711* [itu-t-q711])

SDCCH
Slow Dedicated Control Channel on Um interface; used for signalling and SMS transport in GSM

SDK
Software Development Kit

SIGTRAN
Signaling Transport over IP (*IETF RFC 2719* [ietf-rfc2719])

SIM
Subscriber Identity Module; small chip card storing subscriber identity

Site
A site is a location where one or more BTSs are installed, typically three BTSs for three sectors

SMPP
Short Message Peer-to-Peer; TCP based protocol to interface external entities with an SMSC

SMSC
Short Message Service Center; store-and-forward relay for short messages

SS7
Signaling System No. 7; Classic digital telephony signaling system

SSH
Secure Shell; *IETF RFC 4250* [ietf-rfc4251] to 4254

SSN
Sub-System Number; identifies a given SCCP Service such as MSC, HLR

STP
Signaling Transfer Point; A Router in SS7 Networks

SUA
SCCP User Adaptation; a SIGTRAN Variant (*RFC 3868* [ietf-rfc3868])

syslog
System logging service of UNIX-like operating systems

System Information
A set of downlink messages on the BCCH and SACCH of the Um interface describing properties of the cell and network

TCH
Traffic Channel; used for circuit-switched user traffic (mostly voice) in GSM

TCP
Transmission Control Protocol; (*IETF RFC 793* [ietf-rfc793])

TFTP
Trivial File Transfer Protocol; (*IETF RFC 1350* [ietf-rfc1350])

TRX
Transceiver; element of a BTS serving a single carrier

u-Boot
Boot loader used in various embedded systems

UBI
An MTD wear leveling system to deal with NAND flash in Linux

UBL
Initial bootloader loaded by the TI Davinci SoC

UDP
User Datagram Protocol (*IETF RFC 768* [ietf-rfc768])

UICC
Universal Integrated Chip Card; A smart card according to *ETSI TR 102 216* [etsi-tr102216]

Um interface
U mobile; Radio interface between MS and BTS

uplink
Direction of messages: Signals from the mobile phone towards the network

USIM
Universal Subscriber Identity Module; application running on a UICC to provide subscriber identity for UMTS and GSM networks

VCTCXO
Voltage Controlled, Temperature Compensated Crystal Oscillator; a precision oscillator, superior to a classic crystal oscillator, but inferior to an OCXO

VPLMN
Visited PLMN; the network in which the subscriber is currently registered; may differ from HPLMN when on roaming

VTY
Virtual TeletType; a textual command-line interface for configuration and introspection, e.g. the OsmoBSC configuration file as well as its telnet link on port 4242

A Osmocom TCP/UDP Port Numbers

The Osmocom GSM system utilizes a variety of TCP/IP based protocols. The table below provides a reference as to which port numbers are used by which protocol / interface.

Table 11: TCP/UDP port numbers

L4 Protocol	Port Number	Purpose	Software
UDP	2427	MGCP GW	osmo-bsc_mgcp, osmo-mgw
TCP	2775	SMPP (SMS interface for external programs)	osmo-nitb
TCP	3002	A-bis/IP OML	osmo-bts, osmo-bsc, osmo-nitb
TCP	3003	A-bis/IP RSL	osmo-bts, osmo-bsc, osmo-nitb
TCP	4236	Control Interface	osmo-trx
TCP	4237	telnet (VTY)	osmo-trx
TCP	4238	Control Interface	osmo-bts
TCP	4239	telnet (VTY)	osmo-stp
TCP	4240	telnet (VTY)	osmo-pcu
TCP	4241	telnet (VTY)	osmo-bts
TCP	4242	telnet (VTY)	osmo-nitb, osmo-bsc, cellmgr-ng
TCP	4243	telnet (VTY)	osmo-bsc_mgcp, osmo-mgw
TCP	4244	telnet (VTY)	osmo-bsc_nat
TCP	4245	telnet (VTY)	osmo-sgsn
TCP	4246	telnet (VTY)	osmo-gbproxy
TCP	4247	telnet (VTY)	OsmocomBB
TCP	4249	Control Interface	osmo-nitb, osmo-bsc
TCP	4250	Control Interface	osmo-bsc_nat
TCP	4251	Control Interface	osmo-sgsn
TCP	4252	telnet (VTY)	sysmobts-mgr
TCP	4253	telnet (VTY)	osmo-gtphub
TCP	4254	telnet (VTY)	osmo-msc
TCP	4255	Control Interface	osmo-msc
TCP	4256	telnet (VTY)	osmo-sip-connector
TCP	4257	Control Interface	osmo-ggsn, ggsn (OpenGGSN)
TCP	4258	telnet (VTY)	osmo-hlr
TCP	4259	Control Interface	osmo-hlr
TCP	4260	telnet (VTY)	osmo-ggsn
TCP	4261	telnet (VTY)	osmo-hnbgw
TCP	4262	Control Interface	osmo-hnbgw
TCP	4263	Control Interface	osmo-gbproxy
UDP	4729	GSMTAP	Almost every osmocom project
TCP	5000	A/IP	osmo-bsc, osmo-bsc_nat
UDP	2427	GSMTAP	osmo-pcu, osmo-bts
UDP	23000	GPRS-NS over IP default port	osmo-pcu, osmo-sgsn, osmo-gbproxy

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[18] [3gpp-ts-23-048] 3GPP TS 23.048: Security mechanisms for the (U)SIM application toolkit; Stage 2 http://www.3gpp.org/DynaReport/23048.htm

[19] [3gpp-ts-24-007] 3GPP TS 24.007: Mobile radio interface signalling layer 3; General Aspects http://www.3gpp.org/DynaReport/24007.htm

[20] [3gpp-ts-24-008] 3GPP TS 24.008: Mobile radio interface Layer 3 specification; Core network protocols; Stage 3. http://www.3gpp.org/dynareport/24008.htm

[21] [3gpp-ts-31-101] 3GPP TS 31.101: UICC-terminal interface; Physical and logical characteristics http://www.3gpp.org/DynaReport/31101.htm

[22] [3gpp-ts-31-102] 3GPP TS 31.102: Characteristics of the Universal Subscriber Identity Module (USIM) application http://www.3gpp.org/DynaReport/31102.htm

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