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1 Foreword

Digital cellular networks based on the GSM specification were designed in the late 1980s and first deployed in the early 1990s 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 any 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
• Bernd Schneider of Netzing AG for funding early ip.access nanoBTS support
• On-Waves ehf for being one of the early adopters of OpenBSC and funding a never ending list of features, fixes and general improvement of pretty much all of our GSM network element implementations
• sysmocom, for hosting and funding a lot of Osmocom development, the annual Osmocom Developer Conference and releasing this manual.
• Jan Luebke, Stefan Schmidt, Daniel Willmann, Pablo Neira, Nico Golde, Kevin Redon, Ingo Albrecht, Alexander Huemer,
  Alexander Chemeris, Max Suraev, Tobias Engel, Jacob Erlbeck, Ivan Kluchnikov

• NLnet Foundation, for providing funding for a number of individual work items within the Osmocom universe, such as LTE
  support in OsmoCBC or GPRS/EGPRS support for Ericsson RBS6000.

• WaveMobile Ltd, for many years of sponsoring.

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 benefiting 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/oper-
  ating it,

• providing qualified bug reports, workarounds

• 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.

2.4.3 Trademarks

All trademarks, service marks, trade names, trade dress, product names and logos appearing in this manual are the property of their respective owners. All rights not expressly granted herein are reserved.

For your convenience we have listed below some of the registered trademarks referenced herein. This is not a definitive or complete list of the trademarks used.
2.4.4 Liability

The software is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the License text included with the software for more details.

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 and 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 https://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.

If you would like to obtain professional/commercial support on Osmocom CNI, you can always reach out to sales@sysmocom.de to discuss your support needs. Purchasing support from sysmocom helps to cover the ongoing maintenance of the Osmocom CNI software stack.

4 Overview

4.1 About this manual

This manual should help you getting started with the osmo-e1d software. It will cover aspects of configuring and running osmo-e1d as well as some introduction about its internal architecture and external interfaces.

4.2 About osmo-e1d

osmo-e1d is a driver (implemented as userspace daemon) for a variety of hardware related to the E1 (TDM) interface, such as

- the icEusb USB attached E1 interface
- the e1-tracer USB attached passive E1 tracer

4.3 Credits

osmo-e1d was originally developed in 2019 by Sylvain Munaut alongside the icE1usb project. It subsequently got improved and extended by Harald Welte.

4.4 Architecture

osmo-e1d is a driver system for E1 circuits, which are sometimes also called primary rate (PRI). It typically sits between an E1 hardware interface beneath it and application software above it.
Contrary to older E1 drivers such as DAHDI or mISDN, osmo-e1d runs entirely in userspace, without a need for kernel drivers. This is obviously less computationally efficient, but has other advantages, such as working on unmodified Linux kernels / operating systems, and with a lower risk of software bugs affecting overall system stability. Particularly at low E1 port density and modern hardware, the lower efficiency is not expected to make a big difference.

4.4.1 E1 Interfaces

In osmo-e1d language, an E1 Interface is some kind of underlying hardware that contains one or more Lines. Interfaces are numbered from 0..N and are often abbreviated e.g. as I0 for Interface 0.

4.4.2 E1 Lines

In osmo-e1d language, an E1 Line represents one single E1 circuit within an E1 Interface.

4.5 Hardware support

osmo-e1d currently supports the following hardware:

- Osmocom icE1usb
• Osmocom e1-tracer
• Virtual pair of E1 circuits

4.5.1 icE1usb

The Osmocom icE1usb is an OSHW implementation of a USB-attached hardware interface for up to two E1 circuits (lines).
For more information on the Osmocom icE1usb, see

• data sheet: https://www.sysmocom.de/downloads/icE1usb_data_sheet.pdf
• project wiki: https://osmocom.org/projects/e1-t1-adapter/wiki/ICE40_E1_USB_interface
• product page: https://www.sysmocom.de/products/lab/icE1usb

4.5.2 e1-tracer

The Osmocom e1-tracer is an OSHW implementation of a passive, high-impedance bi-directional E1 tap/tracer/sniffer. It can be used to capture traffic on an unmodified E1 interface.

For more information on the Osmocom e1-tracer, see

• project wiki: https://osmocom.org/projects/e1-t1-adapter/wiki/E1_tracer
• user manual: https://ftp.osmocom.org/docs/latest/e1tracer-usermanual.pdf

4.5.3 vpair

The osmo-e1d vpair is not actual hardware, but a virtual pair of E1 interfaces. It can be used to test E1-using applications without involving a hardware E1 circuit.

5 Installation

This section is a general section providing a high-level overview how to install Osmocom software on your GNU/Linux system. It is important that you choose one of the options outlined below. Trying to mix some packages from a distribution with some packages from osmocom.org while building some other parts from source is likely asking for troubles that could be avoided if you stick to all osmocom software from either one of those sources, without mixing + matching.

5.1 Official Osmocom Binary Packages

The Osmocom project packages most of its software as binary packages for a variety of GNU/Linux distributions, both in rpm and dpkg package formats.

For the most up-to-date information, please check out the related wiki page at https://osmocom.org/projects/cellular-infrastructure/-wiki/Binary_Packages

At the time of this writing there are two main flavours:

• the latest feed (containing the latest tagged version of each program). See https://osmocom.org/projects/cellular-infrastructure/-wiki/Latest_Builds
• the nightly feed (containing automatic nightly builds of each program). See https://osmocom.org/projects/cellular-infrastructure/-wiki/Nightly_Builds
5.2 Distribution Binary Packages

Your GNU/Linux distribution may contain packages of Osmocom software. If you use those packages, please look for any distributions-specific information on how those packages might deviate from upstream, such as for example on Debian GNU/Linux the files located in `/usr/share/doc/osmo-*/README.Debian`.

Please note that Distribution packages usually lag behind the official *upstream* packages the Osmocom project releases. It is a matter of personal preference or policy which packages you use.

5.3 Building from source code

All of Osmocom is Open Source software, so of course the full source code of the related software is released, and you are free to download, build, explore it and hack on it.

The official location for all osmocom source code is at [https://gitea.osmocom.org/](https://gitea.osmocom.org/)

However, if you are just a normal user and not a developer familiar with classic C development on GNU/Linux, we **strongly recommend** you to use some of the binary package options indicated above.

If you know your way around git, make, autotools, pkg-config, etc. by all means, go ahead, don’t be discouraged. We just want to avoid normal users from having to work with unfamiliar tools and wasting time on getting software to build, rather than actually using it.

Some general (possibly outdated) instructions on how to build Osmocom software from source can be found at [https://osmocom.org/-projects/cellular-infrastructure/wiki/Build_from_Source](https://osmocom.org/-projects/cellular-infrastructure/wiki/Build_from_Source)

In general, the usual approach is to

- start with `libosmocore` and all the required libraries and build them in order until you have the full chain of dependencies in place. As a final step, build the actual application you want to use.
- perform `autoreconf -fi` `.configure` and `make install` for each of the projects. Check the `.configure --help` output to see which optional compile-time features you might want to enable or disable.

6 Running osmo-e1d

The `osmo-e1d` executable offers the following command-line arguments:

6.1 SYNOPSIS

`osmo-e1d` [-h] [-V] [-d `DBGMASK`] [-c `CONFIGFILE`]

6.2 OPTIONS

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

- **-V, --version**
  Print the version of osmo-e1d.

- **-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 12 for further information.

- **-c, --config-file `CONFIGFILE`**
  Specify the file and path name of the configuration file to be used. If none is specified, use `osmo-bsc.cfg` in the current working directory.
6.3 Running as a systemd service

Most modern GNU/Linux distributions use systemd to manage processes. We provide an example systemd service unit file in the contrib/systemd/ sub-directory of the source code.

Please see your distribution documentation and/or the generic systemd user manuals for more in-depth information.

The included systemd service unit file assumes your configuration file is stored in /etc/osmocom/, but feel free to adjust this according to your local environment.

This service unit file is also what is used (and installed) by the official dpkg and rpm packages published by Osmocom. For more information, see https://osmocom.org/projects/cellular-infrastructure/wiki/Binary_Packages

On a system utilizing this systemd service unit, you can use the following standard commands:

6.3.1 Starting a service

Example shell command to start the osmo-bsc service

```bash
# systemctl start osmo-bsc
```

6.3.2 Stopping a service

Example shell command to stop the osmo-bsc service

```bash
# systemctl stop osmo-bsc
```

6.3.3 Enabling a service for automatic start on boot

Example shell command to enable the osmo-bsc service

```bash
# systemctl enable osmo-bsc
```

**Note**

This will only affect service starting at the next system boot; it will not start the service if it is not running right now.

6.3.4 Disabling a service from automatic start on boot

Example shell command to disable the osmo-bsc service

```bash
# systemctl disable osmo-bsc
```

6.3.5 Checking current status of a service

Example shell command to check the status of osmo-e1d

```bash
# systemctl status osmo-e1d
```

```
● osmo-e1d.service - Osmocom E1 Interface Daemon
 Loaded: loaded (/etc/systemd/system/osmo-e1d.service; enabled; vendor preset: enabled)
 Active: active (running) since Tue 2022-11-01 13:12:54 CET; 4 days ago
 Main PID: 629 (osmo-e1d)
 Tasks: 2 (limit: 4673)
 Memory: 2.0M
 CPU: 6min 8.464s
```

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7 Client Interface

This chapter documents the Client interface which is used by application programs wanting to send and/or receive data on the E1 circuits served by osmo-e1d.

The interface is based on a unix domain socket and works in the following way:

- osmo-e1d implements the server side of a unix domain socket
- the application program acts as a client program establishing a socket connection to the e1d unix domain socket
- the application program preforms operations such as opening of a specific E1 timeslot on a specific line/interface.
- osmo-e1d passes a file descriptor from the daemon to the client application
- the client application can read/write data from/to the E1 timeslot via this file descriptor

This architecture was chosen to allow for the one file descriptor per timeslot paradigm that is known from other drivers, such as DAHDI.

Each timeslot of each line on each interface can theoretically be opened by a different program. This permits for example control/user plane splits like a signaling gateway + media gateway implemented as separate processes.

When opening a timeslot, the client specifies the mode.

- In RAW mode, the transparent 64kBps bit-stream is passed over the per-timeslot file descriptor. This is mostly used for B-channels / user traffic.
- In HDLC-FCS mode, a (software) HDLC processor is instantiated. It performs flag sequence detection/generation and bit-stuffing. This is mostly used for D-channels / signalling.

Details about the messaging on the unix domain socket can be found in the definitions contained in the include/osmocom/e1d/proto.h header file, as well as the doxygen API documentation generated from it.

7.1 libosmo-e1d client library

To simplify interfacing osmo-e1d from an application, there is a companion library called libosmo-e1d.

It contains functions implementing the above-mentioned client interface protocol and prevents the application developer from having to implement the low-level bits of this interface.

The library is licensed under GNU LGPL-3.0-or-later, which is a weak copyleft license that permits using the library from non-open-source / proprietary applications.

The library offers the following functions:

- initialization / teardown
  - osmo_eldp_client_create()
  - osmo_eldp_client_destroy()
• information querying
  - osmo_e1dp_client_intf_query()
  - osmo_e1dp_client_line_query()
  - osmo_e1dp_client_ts_query()

• configuration
  - osmo_e1dp_client_line_config()

• opening of timeslots
  - osmo_e1dp_client_ts_open()
  - osmo_e1dp_client_ts_open_force()

Details about those functions can be found in the definitions contained in the `include/osmocom/eld/proto_clnt.h` header file.

8 E1 drivers

osmo-e1d was primarily developed for the icE1usb hardware, but also supports some other drivers by now.

8.1 The usb driver for icE1usb and e1-tracer

The usb driver implements the USB interface first implemented by the icE1usb hardware.

For more information on the icEusb, please see its related user manual, published at https://downloads.osmocom.org/docs/latest/icE1usb-usermanual.pdf

Each icEusb device implements one E1 interface with up to two E1 lines. Note that supporting two E1 lines is only supported on very few select USB host controllers. In most cases, your USB host controller will only permit using one of the two lines.

8.1.1 Configuration

osmo-e1d will automatically detect any supported USB devices when starting up. It will dynamically allocate E1 interface and E1 line numbers to those USB devices. However, the order is not guaranteed and particularly in case you have multiple devices, it is strongly recommended to use static configuration.

In this static configuration, you would have a block like

**Example configuration snippet for an icE1usb**

```
interface 2 icE1usb
usb-serial dc697407e7881531
```

This way you reserve/allocate the E1 interface number 2 for the icE1usb with serial number dc697407e7881531. The Serial number is unique and stored in the iSerial string of the USB device descriptor. You can for example use `lsusb -v -d 1d50: | grep iSerial` to obtain it, or check the `dmesg` kernel log after plugging in a device.

8.1.2 Using the usb driver with e1-tracer

The same driver has been slightly extended to also support the passive, bi-directional e1-tracer hardware. The configuration and use is identical to the use with the icE1usb, with the notable difference that a passive tracer can obviously only receive data from E1, but not transmit. The two directions of a E1 circuit are represented as two lines in osmo-e1d.
8.2 The vpair driver for virtual E1 circuits

Sometimes it is useful to be able to interface multiple E1-using applications without a real E1 circuit or any hardware whatsoever. This can be used in automatic / virtualized software testing, but also in case a legacy application is migrate away from real physical E1 circuits.

8.2.1 Configuration

The configuration of the vpair driver is relatively simple. It consists of a single virtual-e1-pair command.

Example configuration snippet for a virtual E1 pair with one E1 line

```
e1d
  virtual-e1-pair 1
```

The above example will create a virtual pair of E1 interfaces, each of those interface with one E1 line.

Log output of the example configuration for 1 virtual pair

```
intf_line.c:184 (I0) Created
intf_line.c:285 (I0:L0) Created
intf_line.c:184 (I1) Created
intf_line.c:285 (I1:L0) Created
```

You can subsequently use the Lines just like you would use physical E1 lines. Any data you transmit on one line will be received on the other line, and vice versa.

9 OCTOI TDMoIP mode

Instead of providing a programmatic client interface ([?]) enabling external applications timeslot-granular access to the data of a E1 line, osmo-e1d also supports an entirely separate mode of operation: TDMoIP using the OCTOI (Osmocom Community TDMoIP) protocol.

In this mode of operation, osmo-e1d acts as interface between an E1 line and a remote system over UDP/IP. This allows you to transparently pass an E1 line over an IP network such as the Internet.

osmo-e1d can operate either as client or as server for the OCTOI protocol.

9.1 osmo-e1d as OCTOI client

Below is an example configuration snippet for operating as an OCTOI client.

Configuration snippet for operating as an OCTOI client

```
e1d
  interface 0 icE1usb
  usb seri al dc697407e7881531
  line 0
  mode ice1usb
  octoi-client 192.168.7.2 10013
  local-bind 0.0.0.0 3333
  account foobar
  mode ice1usb
  ice1usb serial-number dc697407e7881531
  ice1usb line-number 0
```

We specify that Interface 0 Line 0 (I0:L0) of the icE1usb device with serial number dc697407e7881531 shall be used in eloip mode.
we instantiate an OCTOI client to the remote IP 192.168.7.2 / UDP port 10013
we specify to bind locally to INADDR_ANY and local UDP port 3333
we specify the account/user name to tell the server is foobar
we specify that this OCTOI client instance shall use the icE1usb device with the given serial number. This must match the serial number used above when configuring the icE1usb line mode.

There can of course be any number of E1 interfaces/lines and clients; the example just shows one for clarity.

9.2 osmo-e1d as OCTOI server

Below is an example configuration snippet for operating as an OCTOI server.

Configuration snippet for operating as an OCTOI server

```conf
osmo-e1d
  interface 0 icE1usb
    usb-serial dc697407e7881531
    line 0
      mode eloop
  octoi-server
    local-bind 0.0.0.0 10013
    account foobar
      mode icelusb
        icelusb serial-number dc697407e7881531
        icelusb line-number 0
```

we specify that Interface 0 Line 0 (I0:L0) of the icE1usb device with serial number dc697407e7881531 shall be used in eloop mode.
we bind the OCTOI server to UDP port 9999 of INADDR_ANY
we specify a user account foobar
we connect the user account foobar to the icE1usb serial number / line number specified above

There can of course be any number of E1 interfaces/lines and user accounts; the example just shows one for clarity.

10 Osmocom Counters

The following gives an overview of all the types of counters available:

10.1 Osmo Counters (deprecated)

Osmo counters are the oldest type of counters added to Osmocom projects. They are not grouped.

- Printed as part of VTY show stats
- Increment, Decrement
- Accessible through the control interface: counter.<counter_name>
10.2 Rate Counters

Rate counters count rates of events.

- Printed as part of VTY show stats
- Intervals: per second, minute, hour, day or absolute value
- Increment only
- Accessible through the control interface
- Rate counters are grouped and different instances per group can exist

The control interface command to get a counter (group) is:
rate_ctr.per_{sec,min,hour,day,abs}.<group_name>.<idx>.[counter_name]

It is possible to get all counters in a group by omitting the counter name

10.3 Stat Item

Stat items are a grouped replacement for osmo counters.

- Printed as part of VTY show stats
- Replacement for osmo counters
- Not yet available through the control interface
- Grouped and indexed like rate counters
- Items have a unit
- Keeps a list of the last values measured, so could return an average, min, max, std. deviation. So far this is not implemented in any of the reporting options.

10.4 Statistic Levels

There are three levels on which a statistic can be aggregated in Osmocom projects: globally, per-peer and per-subscriber.

10.4.1 Global

These are global statistics.

10.4.2 Peer

These statistics relate to a peer the program connects to such as the NSVC in an SGSN. This level also includes reporting global statistics.

10.4.3 Subscriber

These statistics are related to an individual mobile subscriber. An example would be bytes transferred in an SGSN PDP context. This level also includes global and peer-based statistics.
10.5 Stats Reporter

The stats reporter periodically collects osmo counter, rate counter and stat item values and sends them to a backend. Currently implemented are outputting to the configured log targets and a statsd connector.

10.5.1 Configuring a stats reporter

Periodically printing the statistics to the log can be done in the following way:

**Example 10.1 Log statistics**

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OsmoBSC&gt; enable</td>
<td>OsmoBSC&gt; enable</td>
</tr>
<tr>
<td>OsmoBSC# configure terminal</td>
<td>OsmoBSC# configure terminal</td>
</tr>
<tr>
<td>OsmoBSC(config)# stats interval 60</td>
<td>OsmoBSC(config)# stats interval 60</td>
</tr>
<tr>
<td>OsmoBSC(config)# stats reporter log</td>
<td>OsmoBSC(config)# stats reporter log</td>
</tr>
<tr>
<td>OsmoBSC(config-stats)# level global</td>
<td>OsmoBSC(config-stats)# level global</td>
</tr>
<tr>
<td>OsmoBSC(config-stats)# enable</td>
<td>OsmoBSC(config-stats)# enable</td>
</tr>
</tbody>
</table>

1  The interval determines how often the statistics are reported.
2  Write the statistic information to any configured log target.
3  Report only global statistics (can be global, peer, or subscriber).
4  Enable the reporter, disable will disable it again.

The counter values can also be sent to any aggregation/visualization tool that understands the statsd format, for example a statsd server with graphite or prometheus using the statsd_exporter together with grafana.

The statsd format is specified in [https://github.com/b/statsd_spec](https://github.com/b/statsd_spec)

**Example 10.2 Report statistics to statsd**

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OsmoBSC&gt; enable</td>
<td>OsmoBSC&gt; enable</td>
</tr>
<tr>
<td>OsmoBSC# configure terminal</td>
<td>OsmoBSC# configure terminal</td>
</tr>
<tr>
<td>OsmoBSC(config)# stats interval 10</td>
<td>OsmoBSC(config)# stats interval 10</td>
</tr>
<tr>
<td>OsmoBSC(config)# stats reporter statsd</td>
<td>OsmoBSC(config)# stats reporter statsd</td>
</tr>
<tr>
<td>OsmoBSC(config-stats)# prefix BSC1</td>
<td>OsmoBSC(config-stats)# prefix BSC1</td>
</tr>
<tr>
<td>OsmoBSC(config-stats)# level subscriber</td>
<td>OsmoBSC(config-stats)# level subscriber</td>
</tr>
<tr>
<td>OsmoBSC(config-stats)# remote-ip 1.2.3.4</td>
<td>OsmoBSC(config-stats)# remote-ip 1.2.3.4</td>
</tr>
<tr>
<td>OsmoBSC(config-stats)# remote-port 8125</td>
<td>OsmoBSC(config-stats)# remote-port 8125</td>
</tr>
<tr>
<td>OsmoBSC(config-stats)# enable</td>
<td>OsmoBSC(config-stats)# enable</td>
</tr>
</tbody>
</table>

1  Configure the statsd reporter.
2  Prefix the reported statistics. This is useful to distinguish statistics from multiple instances of the same service.
3  Report only global statistics or include peer or subscriber statistics as well.
4  IP address of the statsd server.
5  UDP port of the statsd server. Statsd by default listens to port 8125.

You can use Netdata ([https://learn.netdata.cloud/](https://learn.netdata.cloud/)) as a statsd server which does not require special configuration to show rate counters. By default all the rate counters will be exposed to the StatsD plugin (listening on 127.0.0.1:8125) and displayed on the Netdata dashboard available via: [http://localhost:19999](http://localhost:19999) The list of available charts which includes all the rate counters reported via statsD is available through: [http://localhost:19999/api/v1/charts](http://localhost:19999/api/v1/charts)
10.6 Socket stats

libosmocore provides features to monitor the status of TCP connections. This can be a helpful source of information when the links between network components are unreliable (e.g. satellite link between BTS and BSC).

**Note**
This feature is only available for certain types of TCP connections. At the moment only RSL/OML connections between OsmoBSC and the connected BTSs can be monitored.

10.6.1 Configuration

The gathering of the TCP connection statistics is done via syscalls. This has to be taken into account for the configuration. Since syscalls are rather expensive and time consuming the overall performance of the application may suffer when many TCP connections are present. This may be the case for BSCs with a large number of BTSs connected to it.

The statistics are gathered in batches per interval. A batch size of 5 would mean that only 5 TCP connections per interval are evaluated and the next 5 connections in the next interval and so on.

It is recommended to choose a large reporting interval and a reasonable small batch size to distribute the syscall load as even as possible.

**Example 10.3** Report statistics to statsd

```
OsmoBSC> enable
OsmoBSC# configure terminal
stats-tcp interval 10
stats-tcp batch-size 5
```

1. Set the gathering interval (sec.)
2. Set how many TCP sockets statistics to gather per interval.

10.6.2 Generated stats items

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tcp:unacked</td>
<td>unacknowledged packets.</td>
</tr>
<tr>
<td>tcp:lost</td>
<td>unacknowledged packets.</td>
</tr>
<tr>
<td>tcp:retrans</td>
<td>lost packets.</td>
</tr>
<tr>
<td>tcp:rrtt</td>
<td>retransmitted packets.</td>
</tr>
<tr>
<td>tcp:rcv_rtt</td>
<td>roundtrip-time (receive).</td>
</tr>
<tr>
<td>tcp:notsent_bytes</td>
<td>bytes not yet sent.</td>
</tr>
<tr>
<td>tcp:rwnd_limited</td>
<td>time (usec) limited by receive window.</td>
</tr>
<tr>
<td>tcp:sndbuf_limited</td>
<td>Time (usec) limited by send buffer.</td>
</tr>
<tr>
<td>tcp:reord_seen</td>
<td>reordering events seen.</td>
</tr>
</tbody>
</table>

The item group index is the file descriptor number. The item group name consists of a static prefix (e.g. "ipa-rsl"), followed by the IP addresses and ports of both peers.
**Example 10.4** VTY output of a stats item group of a TCP connection

```plaintext
stats tcp (15)('ipa-rsl,r=10.9.1.143:38455<->l=10.9.1.162:3003'):
  unacknowledged packets: 0
  lost packets: 0
  retransmitted packets: 0
  roundtrip-time: 583
  roundtrip-time (receive): 0
  bytes not yet sent: 0
  time (usec) limited by receive window: 0
  time (usec) limited by send buffer: 0
  reordering events seen: 0
```

## 11 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 1: VTY Parameter Patterns**

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Example</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.B.C.D</td>
<td>127.0.0.1</td>
<td>An IPv4 address</td>
</tr>
<tr>
<td>A.B.C.D/M</td>
<td>192.168.1.0/24</td>
<td>An IPv4 address and mask</td>
</tr>
<tr>
<td>X::X::X::X/X</td>
<td>::1/128</td>
<td>An IPv6 address and mask</td>
</tr>
<tr>
<td>TEXT</td>
<td>example01</td>
<td>A single string without any spaces, tabs</td>
</tr>
<tr>
<td>TEXT</td>
<td>Some information</td>
<td>A line of text</td>
</tr>
<tr>
<td>(OptionA</td>
<td>OptionB</td>
<td>OptionC)</td>
</tr>
<tr>
<td>&lt;0-10&gt;</td>
<td>5</td>
<td>A number from a range</td>
</tr>
</tbody>
</table>

### 11.1 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.

### 11.2 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.
11.3 Interactive help

The VTY features an interactive help system, designed to help you to efficiently navigate its 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 OsmoMSC VTY. They will work in similar fashion on the other VTY interfaces, while the node structure will differ in each program.

11.3.1 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 OsmoMSC prompt**

```
OsmoMSC> ?
  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 logging
  no        Negate a command or set its defaults
  sms       SMS related commands
  subscriber Operations on a Subscriber
```

* 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**

```
OsmoMSC> show ?
  version   Displays program version
  online-help Online help
  history   Display the session command history
  cs7       ITU-T Signaling System 7
  loggings  Show current logging configuration
  alarms    Show current logging configuration
  talloc-context Show talloc memory hierarchy
  stats     Show statistical values
  asciidoc  Asciidoc generation
  rate-counters Show all rate counters
  fsm       Show information about finite state machines
  fsm-instances Show information about finite state machine instances
  sgs-connections Show SGs interface connections / MMEs
  subscriber Operations on a Subscriber
  bsc       BSC
  connection Subscriber Connections
  transaction Transactions
```

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### 11.3.2 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**

```
OsmoMSC> s
show
```

Type `<tab>` here.

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

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

```
OsmoMSC> show
version online-help history cs7 logging alarms
talloc-context stats asciidoc rate-counters fsm fsm-instances
sgs-connections subscriber bsc connection transaction statistics
sms-queue smpp
```

Type `<tab>` here.

### 11.3.3 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 OsmoMSC VIEW node prompt**

```
OsmoMSC> list
show version
show online-help
list
exit
help
enable
terminal length <0-512>
terminal no length
who
show history
show cs7 instance <0-15> users
```
show cs7 (sua|m3ua|ipa) [<0-65534>]
show cs7 instance <0-15> asp
show cs7 instance <0-15> as (active|all|m3ua|sua)
show cs7 instance <0-15> sccp addressbook
show cs7 instance <0-15> sccp users
show cs7 instance <0-15> sccp ssn <0-65535>
show cs7 instance <0-15> sccp connections
show cs7 instance <0-15> sccp timers
logging enable
logging disable
logging filter all {0|1}
logging color {0|1}
logging timestamp {0|1}
logging print category {0|1}
logging print category-hex {0|1}
logging print level {0|1}
logging print file {0|1|basename} [last]
logging set-log-mask MASK
logging level (rll|cc|mm|rr|mncc|pag|mac|mgcp|ho|db|ref|ctrl|smpp|ranap|vlr|iusc|bssap|gs|lglobal|llapd|llnp|lmux|lmi|lmib|lms|ltr|llgtp|lstat|lgasup|loap|lss7|laccp|lsua|lmgcp|ljibuf|lrspro) (debug|info|notice|error|fatal)
logging level set-all (debug|info|notice|error|fatal)
logging level force-all (debug|info|notice|error|fatal)
no logging level force-all
show logging vty
show alarms
show talloc-context (application|all) (full|brief|DEPTH)
show talloc-context (application|all) (full|brief|DEPTH) tree ADDRESS
show talloc-context (application|all) (full|brief|DEPTH) filter REGEXP
show stats
show stats level (global|peer|subscriber)
show ascidoc counters
show rate-counters
show fsm NAME
show fsm.all
show fsm-instances NAME
show fsm-instances all
show sgs-connections
show subscriber (msisdn|extension|imsi|tmsi|id) ID
show subscriber cache
show bsc
show connection
show transaction
sms send pending
sms delete expired
subscriber create imsi ID
subscriber (msisdn|extension|imsi|tmsi|id) ID sms sender (msisdn|extension|imsi|tmsi|id) SENDER_ID send .LINE
subscriber (msisdn|extension|imsi|tmsi|id) ID silent-sms sender (msisdn|extension|imsi|tmsi|id) SENDER_ID send .LINE
subscriber (msisdn|extension|imsi|tmsi|id) ID silent-call start (any|tch/f|tch/any|sdcc)
subscriber (msisdn|extension|imsi|tmsi|id) ID silent-call stop
subscriber (msisdn|extension|imsi|tmsi|id) ID ussd-notify (0|1) .TEXT
subscriber (msisdn|extension|imsi|tmsi|id) ID ms-test close-loop (a|b|c|d|e|f|i)
subscriber (msisdn|extension|imsi|tmsi|id) ID ms-test open-loop
subscriber (msisdn|extension|imsi|tmsi|id) ID paging
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 OsmoMSC VIEW node with the list of the OsmoMSC NETWORK config node:

Example: Typing list at start of OsmoMSC NETWORK config node prompt

```
OsmoMSC(config-net)# list
  help
  list
  write terminal
  write file
  write memory
  write
  show running-config
  exit
  end
  network country code <1-999>
  mobile network code <0-999>
  short name NAME
  long name NAME
  encryption a5 <0-3> [<0-3>] [<0-3>] [<0-3>]
  authentication (optional|required)
  rrlp mode (none|ms-based|ms-preferred|ass-preferred)
  mm info (0|1)
  timezone <-19-19> (0|15|30|45)
  timezone <-19-19> (0|15|30|45) <0-2>
  no timezone
  periodic location update <6-1530>
  no periodic location update
```

11.3.4 The attribute system

The VTY allows to edit the configuration at runtime. For many VTY commands the configuration change is immediately valid but for some commands a change becomes valid on a certain event only. In some cases it is even necessary to restart the whole process.

To give the user an overview, which configuration change applies when, the VTY implements a system of attribute flags, which can be displayed using the `show` command with the parameter `vty-attributes`

Example: Typing show vty-attributes at the VTY prompt

```
OsmoBSC> show vty-attributes
  Global attributes:
    ^ This command is hidden (check expert mode)
    ! This command applies immediately
    @ This command applies on VTY node exit
  Library specific attributes:
    A This command applies on ASP restart
    I This command applies on IPA link establishment
    L This command applies on E1 line update
  Application specific attributes:
    o This command applies on A-bis OML link (re)establishment
    r This command applies on A-bis RSL link (re)establishment
    l This command applies for newly created lchans
```

The attributes are symbolized through a single ASCII letter (flag) and do exist in three levels. This is more or less due to the technical aspects of the VTY implementation. For the user, the level of an attribute has only informative purpose.
The global attributes, which can be found under the same attribute letter in every osmocom application, exist on the top level. The Library specific attributes below are used in various osmocom libraries. Like with the global attributes the attribute flag letter stays the same throughout every osmocom application here as well. On the third level one can find the application specific attributes. Those are unique to each osmocom application and the attribute letters may have different meanings in different osmocom applications. To make the user more aware of this, lowercase letters were used as attribute flags.

The `list` command with the parameter `with-flags` displays a list of available commands on the current VTY node, along with attribute columns on the left side. Those columns contain the attribute flag letters to indicate to the user how the command behaves in terms of how and when the configuration change takes effect.

**Example: Typing list with-flags at the VTY prompt**

```plaintext
OsmoBSC(config-net-bts)# list with-flags
 help
 list [with-flags]
 show vty-attributes
 show vty-attributes (application|library|global)
 write terminal
 write file [PATH]
 write memory
 write
 show running-config
 exit
 end
 type (unknown|bs11|nanobts|rbs2000|nokia_site|sysmobts)
 description .TEXT
 no description
 band BAND
 cell_identity <0-65535>
 dtx uplink [force]
 dtx downlink
 no dtx uplink
 no dtx downlink
 location_area_code <0-65535>
 base_station_id_code <0-63>
 ipa unit-id <0-6534> <0-255>
 ipa rsl-ip A.B.C.D
 nokia_site skip-reset (0|1)
 nokia_site no-local-rel-conf (0|1)
 nokia_site bts-reset-timer <15-100>

1. This command has no attributes assigned.
2. This command applies on A-bis OML link (re)establishment.
3. This command applies on A-bis RSL link (re)establishment.
4, 5. This command applies immediately.
```

There are multiple columns because a single command may be associated with multiple attributes at the same time. To improve readability each flag letter gets a dedicated column. Empty spaces in the column are marked with a dot (".")

In some cases the listing will contain commands that are associated with no flags at all. Those commands either play an exceptional role (interactive commands outside "configure terminal", vty node navigation commands, commands to show / write the config file) or will require a full restart of the overall process to take effect.

### 11.3.5 The expert mode

Some VTY commands are considered relatively dangerous if used in production operation, so the general approach is to hide them. This means that they don’t show up anywhere but the source code, but can still be executed. On the one hand, this approach...
reduces the risk of an accidental invocation and potential service degradation; on the other, it complicates intentional use of the hidden commands.

The VTY features so-called expert mode, that makes the hidden commands appear in the interactive help, as well as in the XML VTY reference, just like normal ones. This mode can be activated from the VIEW node by invoking the enable command with the parameter expert-mode. It remains active for the individual VTY session, and gets disabled automatically when the user switches back to the VIEW node or terminates the session.

A special attribute in the output of the list with-flags command indicates whether a given command is hidden in normal mode, or is a regular command:

**Example: Hidden commands in the output of the list with-flags command**

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>osmoBSC&gt; enable expert-mode</code></td>
<td>This command enables the expert mode.</td>
</tr>
<tr>
<td><code>OsmoBSC&gt; list with-flags</code></td>
<td>This is a hidden command (only shown in the expert mode).</td>
</tr>
<tr>
<td><code>OsmoBSC&gt; list with-flags</code></td>
<td>This is a regular command that is always shown regardless of the mode.</td>
</tr>
</tbody>
</table>

12 **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.

12.1 **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 list of categories interactively on the vty, type: `logging level ?`
12.2 Log levels

For each of the log categories (see Section 12.1), 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.

12.3 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.
12.4 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`

12.5 Log targets

Each of the log targets represent certain destination for log messages. It can be configured independently by selecting levels (see Section 12.2) for categories (see Section 12.1) as well as filtering (see Section 12.4) and other options like `logging timestamp` for example.

12.5.1 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 12.1 for more details on categories and Section 12.2 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 12.4.

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`

12.5.2 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.
12.5.3 Logging via gsmtap

GSMTAP is normally a pseudo-header format that enables the IP-transport of GSM (or other telecom) protocols that are not normally transported over IP. For example, the most common situation is to enable GSMTAP in OsmoBTS or OsmoPCU to provide GSM-Um air interface capture files over IP, so they can be analyzed in Wireshark.

GSMTAP logging is now a method how Osmocom software can also encapsulate its own log output in GSMTAP frames. We’re not trying to re-invent rsyslog here, but this is very handy when debugging complex issues. It enables the reader of the pcap file containing GSMTAP logging together with other protocol traces to reconstruct exact chain of events. A single pcap file can then contain both the log output of any number of Osmocom programs in the same timeline of the messages on various interfaces in and out of said Osmocom programs.

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.

```
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

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 decrease 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 force-all fatal
```

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**Note**
Every time you generate GSMTAP messages and send it to a unicast (non-broadcast/multicast) IP address, please make sure that the destination IP address actually has a socket open on the specified port, or drops the packets in its packet filter. If unicast GSMTAP messages arrive at a closed destination UDP port, the operating system will likely generate ICMP port unreachable messages. Those ICMP messages in turn will, when arriving at the source (the host on which you run the Osmocom software sending GSMTAP), suppress generation of further GSMTAP messages for some time, resulting in incomplete files. In case of doubt, either send GSMTAP to multicast IP addresses, or run something like `nc -l -u -p 4729 > /dev/null` on the destination host to open the socket at the GSMTAP port and discard anything arriving at it.

12.5.4 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.

12.5.5 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.
12.5.6 Logging to systemd-journal

systemd has been adopted by the majority of modern GNU/Linux distributions. Along with various daemons and utilities it provides systemd-journald [1] - a daemon responsible for event logging (syslog replacement). libosmocore based applications can log messages directly to systemd-journald.

The key difference from other logging targets is that systemd based logging allows to offload rendering of the meta information, such as location (file name, line number), subsystem, and logging level, to systemd-journald. Furthermore, systemd allows to attach arbitrary meta fields to the logging messages [2], which can be used for advanced log filtering.


It was decided to introduce libsystemd as an optional dependency, so it needs to be enabled explicitly at configure/build time:

$ ./configure --enable-systemd-logging

Note

Recent libosmocore packages provided by Osmocom for Debian and CentOS are compiled with libsystemd (https://gerrit.osmocom.org/c/libosmocore/+/22651).

You can configure systemd based logging in two ways:

**Example: systemd-journal target with offloaded rendering**

```
log systemd-journal raw 1
logging filter all 1
logging level set-all notice
```

.raw logging handler, rendering offloaded to systemd.

In this example, logging messages will be passed to systemd without any meta information (time, location, level, category) in the text itself, so all the printing parameters like `logging print file` will be ignored. Instead, the meta information is passed separately as `fields` which can be retrieved from the journal and rendered in any preferred way.

```
# Show Osmocom specific fields
$ journalctl --fields | grep OSMO

# Filter messages by logging subsystem at run-time
$ journalctl OSMO_SUBSYS=DMSC -f

# Render specific fields only
$ journalctl --output=verbose
   --output-fields=SYSLOG_IDENTIFIER,OSMO_SUBSYS,CODE_FILE,CODE_LINE,MESSAGE
```

See `man 7 systemd.journal-fields` for a list of default fields, and `man 1 journalctl` for general information and available formatters.

**Example: systemd-journal target with libosmocore based rendering**

```
log systemd-journal 1
logging filter all 1
logging print file basename
logging print category-hex 0
logging print category 1
logging print level 1
logging timestamp 0 3
logging color 1 3
logging level set-all notice
```

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1. Generic logging handler, rendering is done by libosmocore.
2. Disable timestamping, systemd will timestamp every message anyway.
3. Colored messages can be rendered with `journalctl --output=cat`.

In this example, logging messages will be pre-processed by libosmocore before being passed to systemd. No additional fields will be attached, except the logging level (PRIORITY). This mode is similar to syslog and stderr.

### 12.5.7 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)#
```

### 13 VTY Process and Thread management

Most Osmocom programs provide some support to tune some system settings related to the running process, its threads, its scheduling policies, etc.

All of these settings can be configured through the VTY, either during startup by means of usual config files or through direct human interaction at the telnet VTY interface while the process is running.

#### 13.1 Scheduling Policy

The scheduler to use as well as some of its properties (such as realtime priority) can be configured at any time for the entire process. This sort of functionality is useful in order to increase priority for processes running time-constrained procedures, such as those acting on the Um interface, like `osmo-trx` or `osmo-bts`, where use of this feature is highly recommended.

**Example: Set process to use RR scheduler**

```
cpu-sched
  policy rr 1
```

#### 13.2 CPU-Affinity Mask

Most operating systems allow for some sort of configuration on restricting the amount of CPUs a given process or thread can run on. The procedure is sometimes called as cpu-pinning since it allows to keep different processes pinned on a subset of CPUs to make sure the scheduler won’t run two CPU-hungry processes on the same CPU.

The set of CPUs where each thread is allowed to run on is expressed by means of a bitmask in hexadecimal representation, where the right most bit relates to CPU 0, and the Nth most significant bit relates to CPU N-1. Setting the bit means the process is allowed to run on that CPU, while clearing it means the process is forbidden to run on that CPU.

Hence, for instance a cpu-affinity mask of `0x00` means the thread is not allowed on any CPU, which will cause the thread to stall until a new value is applied. A mask of `0x01` means the thread is only allowed to run on the 1st CPU (CPU 0). A mask of `0xff00` means CPUs 8-15 are allowed, while 0-7 are not.

For single-threaded processes (most of Osmocom are), it is usually enough to set this line in VTY config file as follows:
Allow main thread (the one managing the VTY) only on CPU 0

Or otherwise:

Allow all threads only on CPU 0

For multi-threaded processes, it may be desired to run some threads on a subset of CPUs while another subset may run on another one. In order to identify threads, one can either use the TID of the thread (each thread has its own PID in Linux), or its specific Thread Name in case it has been set by the application.

The related information on all threads available in the process can be listed through VTY. This allows identifying quickly the different threads, its current cpu-affinity mask, etc.

**Example: Get osmo-trx Thread list information from VTY**

```
OsmoTRX> show cpu-sched threads
Thread list for PID 338609:
TID: 338609, NAME: 'osmo-trx-uhd', cpu-affinity: 0x3
TID: 338610, NAME: 'osmo-trx-uhd', cpu-affinity: 0x3
TID: 338611, NAME: 'osmo-trx-uhd', cpu-affinity: 0x3
TID: 338629, NAME: 'osmo-trx-uhd', cpu-affinity: 0x3
TID: 338630, NAME: 'osmo-trx-uhd', cpu-affinity: 0x3
TID: 338631, NAME: 'osmo-trx-uhd', cpu-affinity: 0x3
TID: 338634, NAME: 'UHDAsyncEvent', cpu-affinity: 0x3
TID: 338635, NAME: 'TxLower', cpu-affinity: 0x3
TID: 338636, NAME: 'RxLower', cpu-affinity: 0x3
TID: 338637, NAME: 'RxUpper0', cpu-affinity: 0x3
TID: 338638, NAME: 'TxUpper0', cpu-affinity: 0x3
TID: 338639, NAME: 'RxUpper1', cpu-affinity: 0x3
TID: 338640, NAME: 'TxUpper1', cpu-affinity: 0x3
```

At runtime, one can change the cpu-affinity mask for a given thread identifying it by either TID or name:

**Example: Set CPU-affinity from VTY telnet interface**

```
OsmoTRX> cpu-affinity TxLower 0x02
OsmoTRX> cpu-affinity TxLower 0x03
```

Allow thread named **TxLower (338635)** only on CPU 1

Allow with TID **338636 (RxLower)** only on CPU 0 and 1

Since thread names are set dynamically by the process during startup or at a later point after creating the thread itself, One may need to specify in the config file that the mask must be applied by the thread itself once being configured rather than trying to apply it immediately. To specify so, the `delay` keyword is using when configuring in the VTY. If the `delay` keyword is not used, the VTY will report error and fail at startup when trying to apply a cpu-affinity mask for a yet-to-be-created thread.

**Example: Set CPU-affinity from VTY config file**

```
cpu-sched
cpu-affinity TxLower 0x01 delay
```

Allow thread named **TxLower (338635)** only on CPU 1. It will be applied by the thread itself when created.
14 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

AQPSK
Adaptive QPSK, a modulation scheme used by VAMOS channels on Downlink

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

CBC
Cell Broadcast Centre; central entity of Cell Broadcast service

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

CBS
Cell Broadcast Service

CBSP
Cell Broadcast Service Protocol (3GPP TS 48.049 [3gpp-ts-48-049])

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

CSFB
Circuit-Switched Fall Back; Mechanism for switching from LTE/EUTRAN to UTRAN/GERAN when circuit-switched services such as voice telephony are required.

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

DSCP
Differentiated Services Code Point (IETF RFC 2474 [ietf-rfc2474])

DSP
Digital Signal Processor

dvinixload
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
EIR
Equipment Identity Register; core network element that stores and manages IMEI numbers

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

GPRS
General Packet Radio Service; the packet switched 2G technology

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

GSUP
Generic Subscriber Update Protocol. Osmocom-specific alternative to TCAP/MAP

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

HNB-GW
Home NodeB Gateway. Entity between femtocells (Home NodeB) and CN in 3G/UMTS.

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 14-digit decimal number to globally identify a mobile device, optionally with a 15th checksum digit

IMEISV
IMEI software version; unique 14-digit decimal number to globally identify a mobile device (same as IMEI) plus two software version digits (total digits: 16)

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 [ietf-rfc791])

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

Iu
Interface in 3G/UMTS between RAN and CN

IuCS
Iu interface for circuit-switched domain. Used in 3G/UMTS between RAN and MSC

IuPS
Iu interface for packet-switched domain. Used in 3G/UMTS between RAN and SGSN

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

LU
Location Updating; can be of type IMSI-Attach or Periodic. Procedure that indicates a subscriber’s physical presence in a given radio cell.

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

**MNCC**
Mobile Network Call Control; Unix domain socket based Interface between MSC and external call control entity like osmo-sip-connector

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

**MO**
Mobile Originated. Direction from Mobile (MS/UE) to Network

**MS**
Mobile Station; a mobile phone / GSM Modem

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

**MSC pool**
A number of redundant MSCs serving the same core network, which a BSC / RNC distributes load across; see also the "MSC Pooling" chapter in OsmoBSC’s user manual [userman-osmobsc] and 3GPP TS 23.236 [3gpp-ts-23-236]

**MSISDN**
Mobile Subscriber ISDN Number; telephone number of the subscriber

**MT**
Mobile Terminated. Direction from Network to Mobile (MS/UE)

**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

**NRI**
Network Resource Indicator, typically 10 bits of a TMSI indicating which MSC of an MSC pool attached the subscriber; see also the "MSC Pooling" chapter in OsmoBSC’s user manual [userman-osmobsc] and 3GPP TS 23.236 [3gpp-ts-23-236]

**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

PCP
Priority Code Point (IEEE 802.1Q [?])

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

PDCCH
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

SGs
Interface between MSC (GSM/UMTS) and MME (LTE/EPC) to facilitate CSFB and SMS.

SGSN
Serving GPRS Support Node; Core network element for packet-switched services in GSM and UMTS.

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

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

SS
Supplementary Services; query and set various service parameters between subscriber and core network (e.g. USSD, 3rd-party calls, hold/retrieve, advice-of-charge, call deflection)
SSH
Secure Shell; \textit{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 (\textit{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; \textit{(IETF RFC 793} [ietf-rfc793])

TFTP
Trivial File Transfer Protocol; \textit{(IETF RFC 1350} [ietf-rfc1350])

TOS
Type Of Service; bit-field in IPv4 header, now re-used as DSCP \textit{(IETF RFC 791} [ietf-rfc791])

TRX
Transceiver; element of a BTS serving a single carrier

TS
Technical Specification

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 \textit{(IETF RFC 768} [ietf-rfc768])

UICC
Universal Integrated Chip Card; A smart card according to \textit{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

USSD
Unstructured Supplementary Service Data; textual dialog between subscriber and core network, e.g. \texttt{*100 \rightarrow Your extension is 1234}
VAMOS
Voice services over Adaptive Multi-user channels on One Slot; an optional extension for GSM specified in Release 9 of 3GPP GERAN specifications ([3GPP TS 48.018](https://www.3gpp.org/ftp/Specs/html-info/48018.htm)) allowing two independent UEs to transmit and receive simultaneously on traffic channels

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

VLAN
Virtual LAN in the context of Ethernet ([IEEE 802.1Q](https://standards.ieee.org/standard/802.1Q-2018.html))

VLR
Visitor Location Register; volatile storage of attached subscribers in the MSC

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

VTY
Virtual Teletype; 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>
<thead>
<tr>
<th>Protocol</th>
<th>Port Number</th>
<th>Purpose</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDP</td>
<td>1984</td>
<td>Osmux</td>
<td>osmo-mgw, osmo-bts</td>
</tr>
<tr>
<td>UDP</td>
<td>2427</td>
<td>MGCP GW</td>
<td>osmo-bsc_mgcp, osmo-mgw</td>
</tr>
<tr>
<td>TCP</td>
<td>2775</td>
<td>SMPP (SMS interface for external programs)</td>
<td>osmo-nitb</td>
</tr>
<tr>
<td>TCP</td>
<td>3002</td>
<td>A-bis/IP OML</td>
<td>osmo-bts, osmo-bsc, osmo-nitb</td>
</tr>
<tr>
<td>TCP</td>
<td>3003</td>
<td>A-bis/IP RSL</td>
<td>osmo-bts, osmo-bsc, osmo-nitb</td>
</tr>
<tr>
<td>TCP</td>
<td>4227</td>
<td>telnet (VTY)</td>
<td>osmo-pcap-client</td>
</tr>
<tr>
<td>TCP</td>
<td>4228</td>
<td>telnet (VTY)</td>
<td>osmo-pcap-server</td>
</tr>
<tr>
<td>TCP</td>
<td>4236</td>
<td>Control Interface</td>
<td>osmo-trx</td>
</tr>
<tr>
<td>TCP</td>
<td>4237</td>
<td>telnet (VTY)</td>
<td>osmo-trx</td>
</tr>
<tr>
<td>TCP</td>
<td>4238</td>
<td>Control Interface</td>
<td>osmo-bts</td>
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<tr>
<td>TCP</td>
<td>4239</td>
<td>telnet (VTY)</td>
<td>osmo-stp</td>
</tr>
<tr>
<td>TCP</td>
<td>4240</td>
<td>telnet (VTY)</td>
<td>osmo-pcu</td>
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<tr>
<td>TCP</td>
<td>4241</td>
<td>telnet (VTY)</td>
<td>osmo-bts</td>
</tr>
<tr>
<td>TCP</td>
<td>4242</td>
<td>telnet (VTY)</td>
<td>osmo-nitb, osmo-bsc, cellmgr-ng</td>
</tr>
<tr>
<td>TCP</td>
<td>4243</td>
<td>telnet (VTY)</td>
<td>osmo-bsc_mgcp, osmo-mgw</td>
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<tr>
<td>TCP</td>
<td>4244</td>
<td>telnet (VTY)</td>
<td>osmo-bsc_nat</td>
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<td>TCP</td>
<td>4245</td>
<td>telnet (VTY)</td>
<td>osmo-sgsn</td>
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<tr>
<td>TCP</td>
<td>4246</td>
<td>telnet (VTY)</td>
<td>osmo-gbproxy</td>
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<tr>
<td>TCP</td>
<td>4247</td>
<td>telnet (VTY)</td>
<td>OsmocomBB</td>
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<td>TCP</td>
<td>4249</td>
<td>Control Interface</td>
<td>osmo-nitb, osmo-bsc</td>
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<tr>
<td>TCP</td>
<td>4250</td>
<td>Control Interface</td>
<td>osmo-bsc_nat</td>
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<td>TCP</td>
<td>4251</td>
<td>Control Interface</td>
<td>osmo-sgsn</td>
</tr>
<tr>
<td>TCP</td>
<td>4252</td>
<td>telnet (VTY)</td>
<td>sysmobts-mgr</td>
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<tr>
<td>TCP</td>
<td>4253</td>
<td>telnet (VTY)</td>
<td>osmo-gtphub</td>
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<tr>
<td>TCP</td>
<td>4254</td>
<td>telnet (VTY)</td>
<td>osmo-msc</td>
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Table 2: (continued)

<table>
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<tbody>
<tr>
<td>TCP</td>
<td>4255</td>
<td>Control Interface</td>
<td>osmo-msc</td>
</tr>
<tr>
<td>TCP</td>
<td>4256</td>
<td>telnet (VTY)</td>
<td>osmo-sip-connector</td>
</tr>
<tr>
<td>TCP</td>
<td>4257</td>
<td>Control Interface</td>
<td>osmo-ggsn, ggsn (OpenGGSN)</td>
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<td>TCP</td>
<td>4258</td>
<td>telnet (VTY)</td>
<td>osmo-hlr</td>
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<td>4259</td>
<td>Control Interface</td>
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<td>osmo-ggsn</td>
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<td>4261</td>
<td>telnet (VTY)</td>
<td>osmo-hnbgw</td>
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<td>TCP</td>
<td>4262</td>
<td>Control Interface</td>
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<td>TCP</td>
<td>4263</td>
<td>Control Interface</td>
<td>osmo-gbproxy</td>
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<tr>
<td>TCP</td>
<td>4264</td>
<td>telnet (VTY)</td>
<td>osmo-cbc</td>
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<td>4265</td>
<td>Control Interface</td>
<td>osmo-cbc</td>
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<td>TCP</td>
<td>4266</td>
<td>D-GSM MS Lookup: mDNS serve</td>
<td>osmo-hlr</td>
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<td>TCP</td>
<td>4267</td>
<td>Control Interface</td>
<td>osmo-ingw</td>
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<td>TCP</td>
<td>4268</td>
<td>telnet (VTY)</td>
<td>osmo-uecups</td>
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<td>UECUPS</td>
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<td>osmo-e1d</td>
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<td>TCP</td>
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<td>telnet (VTY)</td>
<td>osmo-isdntap</td>
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<td>4271</td>
<td>telnet (VTY)</td>
<td>osmo-smlc</td>
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<td>4272</td>
<td>Control Interface</td>
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<td>4273</td>
<td>telnet (VTY)</td>
<td>osmo-hnodeb</td>
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<tr>
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<td>4274</td>
<td>Control Interface</td>
<td>osmo-hnodeb</td>
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<tr>
<td>TCP</td>
<td>4275</td>
<td>telnet (VTY)</td>
<td>osmo-upf</td>
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<td>4276</td>
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<tr>
<td>TCP</td>
<td>4277</td>
<td>telnet (VTY)</td>
<td>osmo-pfcp-tool</td>
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<tr>
<td>TCP</td>
<td>4278</td>
<td>Control Interface</td>
<td>osmo-pfcp-tool</td>
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<tr>
<td>UDP</td>
<td>4729</td>
<td>GSMTAP</td>
<td>Almost every osmocom project</td>
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<td>TCP</td>
<td>5000</td>
<td>A/IP</td>
<td>osmo-bsc, osmo-bsc_nat</td>
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<tr>
<td>UDP</td>
<td>23000</td>
<td>GPRS-NS over IP default port</td>
<td>osmo-pcu, osmo-sgsn, osmo-gbproxy</td>
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<tr>
<td>TCP</td>
<td>48049</td>
<td>BSC-CBC (CBSP) default port</td>
<td>osmo-bsc, osmo-cbc</td>
</tr>
</tbody>
</table>

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