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<td>1</td>
<td>November 30th, 2019</td>
<td>Initial version</td>
<td>HW</td>
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1 Foreword

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

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

In 2008 Dieter Spaar and I started to experiment with inexpensive end-of-life surplus Siemens GSM BTSs. We learned about the A-bis protocol specifications, reviewed protocol traces and started to implement the BSC-side of the A-bis protocol as something originally called bs11-abis. All of this was just for fun, in order to learn more and to boldly go where no Free Software developer has gone before. The goal was to learn and to bring Free Software into a domain that despite its ubiquity, had not yet seen 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 Luebbe, Stefan Schmidt, Daniel Willmann, Pablo Neira, Nico Golde, Kevin Redon, Ingo Albrecht, Alexander Huemer, Alexander Chemeris, Max Suraev, Tobias Engel, Jacob Erlbeck, Ivan Kluchnikov

May the source be with you!
— Harald Welte, Osmocom.org and OpenBSC founder, January 2016.

1.2 Endorsements

This version of the manual is endorsed by Harald Welte as the official version of the manual.
While the GFDL license (see Appendix C) permits anyone to create and distribute modified versions of this manual, such modified versions must remove the above endorsement.

2 Preface

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

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

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

2.1 FOSS lives by contribution!

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

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

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

We’re looking forward to receiving your contributions.

2.2 Osmocom and sysmocom

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

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

As part of this work, sysmocom has also created the manual you are reading.
At sysmocom, we draw a clear line between what is the Osmocom FOSS project, and what is sysmocom as a commercial entity. Under no circumstances does participation in the FOSS projects require any commercial relationship with sysmocom as a company.
2.3 Corrections

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

2.4 Legal disclaimers

2.4.1 Spectrum License

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

⚠️ Warning

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

2.4.2 Software License

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

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

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

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

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

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.

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sysmocom® and sysmoBTS® are registered trademarks of sysmocom - systems for mobile communications GmbH.

ip.access® and nanoBTS® are registered trademarks of ip.access Ltd.

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

4.1 About OsmoHNBGW

OsmoHNBGW implements the Home NodeB Gateway function in the 3G network architecture. It serves as a gateway between the classic 3G core network (CN) domain with its IuCS and IuPS interface and the femtocell based RAN.

A typical 3G network consisting of Osmocom components is illustrated in the following diagram:

![Typical 3G network architecture diagram](image)

Figure 1: Typical 3G network architecture used with OsmoHNBGW

The HNB-GW performs a translation interface between the IuCS/IuPS interfaces on the one hand side, and the Iuh interface on the other hand:

<table>
<thead>
<tr>
<th>Iuh</th>
<th>IuCS/IuPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAS</td>
<td>+---------+</td>
</tr>
<tr>
<td>Non-Access Stratum</td>
<td>CC</td>
</tr>
<tr>
<td>Access Stratum</td>
<td>HNBAP</td>
</tr>
<tr>
<td>RUA</td>
<td>M3UA</td>
</tr>
<tr>
<td>SCTP</td>
<td>SCEPT</td>
</tr>
<tr>
<td>IP</td>
<td>IP</td>
</tr>
</tbody>
</table>

On the femtocell (Home NodeB) side, OsmoHNBGW implements the Iuh interface as specified by 3GPP.

4.2 The Iuh interface

Iuh consists of the following sub-layers:

- HNBAP (Home NodeB Application Part)
- RUA (RANAP User Adaptation, between RANAP and SCTP)

5 Running OsmoHNBGW

The OsmoHNBGW executable (`osmo-hnbgw`) offers the following command-line arguments:
5.1 SYNOPSIS

```bash
```

5.2 OPTIONS

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

- **-V, --version**
  Print the compile-time version number of the OsmoHNBGW program

- **-d, --debug DBGMASK,DBGLEVELS**
  Set the log subsystems and levels for logging to stderr. This has mostly been superseded by VTY-based logging configuration, see Section 7 for further information.

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

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

- **-s, --disable-color**
  Disable colors for logging to stderr. This has mostly been deprecated by VTY based logging configuration, see Section 7 for more information.

- **-T, --timestamp**
  Enable time-stamping of log messages to stderr. This has mostly been deprecated by VTY based logging configuration, see Section 7 for more information.

- **-e, --log-level LOGLEVEL**
  Set the global log level for logging to stderr. This has mostly been deprecated by VTY based logging configuration, see Section 7 for more information.

5.3 Multiple instances

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

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

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

The Iuh interface can be bound to an individual port:

```plaintext
hnbgw
iuh
  local-ip 0.0.0.0
  local-port 29169
```
For the following links, OsmoHNBGW acts as a client and does not listen/bind to a specific interface, and will hence not encounter conflicts for multiple instances running on the same interface:

- The SCCP/M3UA links are established by OsmoHNBGW contacting an STP.
- The MGCP link is established by OsmoHNBGW contacting an MGW.
- The PFCP link is established by OsmoHNBGW contacting a UPF.

To run multiple OsmoHNBGW instances on the same SCCP routing, each HNBGW has to configure a distinct point-code, see Section 5.4.1.

### 5.4 Configuring Primary Links

#### 5.4.1 Configure SCCP/M3UA to connect to an MSC’s IuCS and an SGSN’s IuPS interface

OsmoHNBGW acts as client to contact an STP instance and establish an SCCP/M3UA link.

An example configuration of OsmoHNBGW’s SCCP link:

```plaintext
  cs7 instance 0
  point-code 0.23.5
  asp asp-clnt-OsmoHNBGW 2905 0 m3ua
  remote-ip 127.0.0.1
  sctp-role client
  sccp-address msc
  routing-indicator PC
  point-code 0.23.1
  sccp-address sgsn
  routing-indicator PC
  point-code 0.23.2
  hnbgw
  iucs
  remote-addr msc
  iups
  remote-addr sgsn
```

This configuration is explained in detail in Section 8.

#### 5.4.2 Configure RUA to accept Iuh connections from hNodeB

OsmoHNBGW acts as server to accept Iuh connections from hNodeB devices.

An example configuration for OsmoHNBGW’s RUA server:

```plaintext
  hnbgw
  iuh
  local-ip 10.9.8.7
  local-port 29169
```
5.4.3 Configure co-located media gateway

OsmoHNBGW requires a co-located OsmoMGW instance. The purpose of the co-located media gateway is to relay the RTP traffic between hNodeB and the core network.

For security reasons the RAN network is kept separate and isolated from the core network. Both networks will usually have no transparent routing in between them. The co-located media gateway provides an interface between hNodeB and core network across this boundary.

The configuration is done under the hnbgw node along with iucs and iups.

An example configuration for OsmoHNBGW’s MGCP client:

```
hnbgw
  mgcp
    mgw remote-ip 127.0.0.1
    mgw remote-port 2427
    mgw reset-endpoint rtpbridge/*
```

5.4.4 Configure co-located User Plane Function

OsmoHNBGW optionally supports relaying the GTP user plane via a co-located UPF, which is controlled by the PFCP protocol. PFCP support is optional at compile time, as well as run time. To use a co-located UPF,

- osmo-hnbgw needs to be compiled with `configure --enable-pfcp`,
- and osmo-hnbgw.cfg needs to configure a `pfcp / remote-addr` and `local-addr`.

The following example configures OsmoHNBGW to associate via PFCP with a UPF listening on UDP 127.0.0.2:8805, ready to setup GTP tunnel relays.

```
hnbgw
  pfcp
    remote-addr 127.0.0.2
    local-addr 127.0.0.1
```

3GPP TS 29.244 4.2.2 specifies that PFCP Request messages shall be sent to UDP port 8805, i.e. the PFCP port is fixed as 8805 and currently not configurable in osmo-hnbgw.

Setting a `local-addr` is required: the PFCP protocol features a Node ID, which uniquely identifies PFCP peers across different interfaces. According to the PFCP specification, the Node ID can be a fully-qualified domain name (FQDN) or an IP address. Currently, osmo-hnbgw has no support for using an FQDN as Node ID, and so far uses the `local-addr` as local Node ID— hence the `local-addr` must not be "0.0.0.0", which is an unfortunate consequence. This is likely to improve in the future, see https://osmocom.org/issues/5647.

6 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 on 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.

<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</td>
<td>::1</td>
<td>An IPv6 address</td>
</tr>
<tr>
<td>X:X::X:X/M</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>

### 6.1 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.

6.2 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.

6.3 Interactive help

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

Note

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

6.3.1 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  

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>show</td>
<td>Show running system information</td>
</tr>
<tr>
<td>list</td>
<td>Print command list</td>
</tr>
<tr>
<td>exit</td>
<td>Exit current mode and down to previous mode</td>
</tr>
<tr>
<td>help</td>
<td>Description of the interactive help system</td>
</tr>
<tr>
<td>enable</td>
<td>Turn on privileged mode command</td>
</tr>
<tr>
<td>terminal</td>
<td>Set terminal line parameters</td>
</tr>
<tr>
<td>who</td>
<td>Display who is on vty</td>
</tr>
<tr>
<td>logging</td>
<td>Configure logging</td>
</tr>
<tr>
<td>no</td>
<td>Negate a command or set its defaults</td>
</tr>
<tr>
<td>sms</td>
<td>SMS related commands</td>
</tr>
<tr>
<td>subscriber</td>
<td>Operations on a Subscriber</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>version</td>
<td>Displays program version</td>
</tr>
<tr>
<td>online-help</td>
<td>Online help</td>
</tr>
<tr>
<td>history</td>
<td>Display the session command history</td>
</tr>
<tr>
<td>cs7</td>
<td>ITU-T Signaling System 7</td>
</tr>
<tr>
<td>logging</td>
<td>Show current logging configuration</td>
</tr>
<tr>
<td>alarms</td>
<td>Show current logging configuration</td>
</tr>
<tr>
<td>talloc-context</td>
<td>Show talloc memory hierarchy</td>
</tr>
<tr>
<td>stats</td>
<td>Show statistical values</td>
</tr>
<tr>
<td>asciidoc</td>
<td>Asciidoc generation</td>
</tr>
<tr>
<td>rate-counters</td>
<td>Show all rate counters</td>
</tr>
<tr>
<td>fsm</td>
<td>Show information about finite state machines</td>
</tr>
<tr>
<td>fsm-instances</td>
<td>Show information about finite state machine instances</td>
</tr>
<tr>
<td>sgs-connections</td>
<td>Show SGs interface connections / MMEs</td>
</tr>
<tr>
<td>subscriber</td>
<td>Operations on a Subscriber</td>
</tr>
<tr>
<td>bsc</td>
<td>BSC</td>
</tr>
<tr>
<td>connection</td>
<td>Subscriber Connections</td>
</tr>
<tr>
<td>transaction</td>
<td>Transactions</td>
</tr>
<tr>
<td>statistics</td>
<td>Display network statistics</td>
</tr>
<tr>
<td>sms-queue</td>
<td>Display SMSqueue statistics</td>
</tr>
</tbody>
</table>

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

You may pick the bsc object and type ? again:

**Example: Typing ? after show bsc**

OsmoMSC> show bsc

By presenting <cr> as the only option, the VTY tells you that your command is complete without any remaining arguments being available, and that you should hit enter, a.k.a. "carriage return".
6.3.2 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
```

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
```

6.3.3 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
```

```
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 NETWORK config 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
```
6.3.4 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

```
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 <0-65534> <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.

#### 6.3.5 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**

```plaintext
OsmoBSC> enable expert-mode
OsmoBSC# list with-flags
... ^ bts <0-255> (activate-all-lchan|deactivate-all-lchan)
^ bts <0-255> trx <0-255> (activate-all-lchan|deactivate-all-lchan)
   bts <0-255> trx <0-255> timeslot <0-7> sub-slot <0-7> mdcx A.B.C.D <0-65535>
^ bts <0-255> trx <0-255> timeslot <0-7> sub-slot <0-7> (borken|unused)
   bts <0-255> trx <0-255> timeslot <0-7> sub-slot <0-7> handover <0-255>
   bts <0-255> trx <0-255> timeslot <0-7> sub-slot <0-7> assignment
   bts <0-255> smacb-command (normal|schedule|default) <1-4> HEXSTRING
...```

1 This command enables the *expert* mode.

2, 3, 4 This is a hidden command (only shown in the *expert* mode).

5, 6, 7, 8 This is a regular command that is always shown regardless of the mode.

### 7 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.

#### 7.1 Log categories

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

For each of the log categories (see Section 7.1), 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.

7.3 Log printing options

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

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

- **log print category**  
  Prefix each log message with the category name.

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

- **log print level**  
  Prefix each log message with the name of the log level.

- **log print file**  
  Prefix each log message with the source file and line number. Append the keyword `last` to append the file information instead of prefixing it.
7.4 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`

7.5 Log targets

Each of the log targets represent certain destination for log messages. It can be configured independently by selecting levels (see Section 7.2) for categories (see Section 7.1) as well as filtering (see Section 7.4) and other options like `logging timestamp`, for example.

7.5.1 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 7.1 for more details on categories and Section 7.2 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 7.4.

---

**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`

7.5.2 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:
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.

### 7.5.3 Logging via gsmtap

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

It’s configured as follows:

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

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

![Wireshark with logs delivered over GSMTAP](image)

**Figure 2:** Wireshark with logs delivered over GSMTAP

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

```
```
7.5.4 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.

7.5.5 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.
7.5.6 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
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
logging filter all 1
logging print file basename
logging print category-hex 0
logging print category 1
logging print level 1
logging timestamp 0
ing
logging color 1
ing
logging level set-all notice

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.

### 7.5.7 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)#
```

### 8 Configure SCCP/M3UA

All CNI programs using SCCP/M3UA act as M3UA ASP role and SCTP client, expecting to connect to a Signalling Gateway (STP/SG) implementing the M3UA SG role as SCTP server. The STP/SG then routes M3UA messages between its ASPs, typically by point-codes.

For an introduction about SCCP/M3UA/SS7/SIGTRAN technology, please see the chapter *Signaling Networks: SS7 and SIGTRAN* in the OsmoSTP user manual.

In an all-Osmocom CNI, the typical simple/minimal usage is:

- OsmoSTP acts as the STP/SG (server role) and routes between the ASP.
- All other Osmocom CNI programs act as SCTP client and provide ASP implementations.

For example, in an all-Osmocom minimal setup,

- OsmoMSC contacts an OsmoSTP and subscribes its point-code 0.23.1;
- then OsmoBSC also contacts the same OsmoSTP, subscribes with its own point-code 1.23.3.
- Using these established links, OsmoBSC initiates an A-interface link by directing a BSSAP RESET message to the MSC’s point-code 0.23.1,
• and the RESET ACK response from the MSC is routed back to the BSC’s point-code 1.23.3.

The details of SCCP/M3UA are configured in the cs7 section of the VTY configuration.

Osmocom programs automatically configure missing SCCP/M3UA configuration, by assuming sane defaults for small/minimal all-Osmocom installations, which may not be what you want in larger networks integrating with non-Osmocom core network elements.

If no explicit routing-key is set, it may be determined at runtime by negotiation with OsmoSTP — see OsmoSTP manual chapter "Osmocom M3UA Routing Key Management Extensions", regarding config option accept-asp-connections dynamic-permitted.

The complete active configuration of an Osmocom program can be obtained by the VTY command show cs7 config (the usual show running-config omits automatically configured items). Here is an example of OsmoMSC’s default configuration:

```
OsmoMSC> show cs7 config
 cs7 instance 0
 point-code 0.23.1
 asp asp-clnt-OsmoMSC-A-Iu 2905 0 m3ua
 remote-ip 127.0.0.1
 sctp-role client
 as as-clnt-OsmoMSC-A-Iu m3ua
 asp asp-clnt-OsmoMSC-A-Iu
 routing-key 2 0.23.1
```

At the time of writing, SCCP/M3UA links involving Osmocom program are:

• A-interface: OsmoBSC to OsmoMSC
• IuCS-interface: OsmoHNBGW to OsmoMSC
• IuPS-interface: OsmoHNBGW to OsmoSGSN
• Lb-interface: OsmoSMLC to OsmoBSC

On the SCTP/IP level, those connections are actually all established from the respective program (BSC, MSC, HNBGW, SGSN, SMLC) to OsmoSTP. Hence, if you look at the traffic in a protocol analyzer like wireshark, at IP level, you will see each of those programs establishing an SCTP association from a random local IP to the well-known SCTP port for M3UA (2905) at the OsmoSTP.

Those star-connections for M3UA/SCTP then are the transport network for higher level protocols like SCCP. OsmoSTP then acts as central router for SCCP-level message exchange between all the connected programs.

### 8.1 Connect to STP Instance

Establishing an SCCP/M3UA link towards a remote STP instance can be configured as:

```
 cs7 instance 0
 asp my-as 2905 0 m3ua
 # IP address of the remote STP:
 remote-ip 10.23.24.1
 # optional: local bind to a specific IP
 local-ip 10.9.8.7
```

Be aware that such an asp needs to be linked to an as, see Section 8.5.

By default, an STP instance is assumed to listen on the default M3UA port (2905) on the local host. That means in general 127.0.0.1 will be used as default remote SCTP address, and ::1 will be added to the SCTP association if IPv6 support is available on the system.
**Note**
OsmoSTP listens by default on `::` if IPv6 is enabled on the system, and on `0.0.0.0` otherwise. Address `::` actually superseeds `0.0.0.0`, meaning it will listen on all IPv4 and IPv6 addresses available on the system.

---

**Caution**
Some applications overwrite the default target remote address to be *localhost*. If IPv6 support is available on the system, *localhost* will usually resolve to `::1`, otherwise it will usually resolve to `127.0.0.1`.

---

### 8.2 Local Point-Code

Each CNI program on an SCCP/M3UA link typically has a local point-code, configurable by:

```
cs7 instance 0
  point-code 7.65.4
```

If an explicit routing context is configured, this point-code is repeated in the *routing-key* configuration:

```
cs7 instance 0
  point-code 0.23.1
  as my-as m3ua
  routing-key 2 0.23.1
```

See also Section 8.4.

### 8.3 Remote Point-Code

Programs establishing communication across SCCP links need a remote SCCP address, typically by point-code, to contact. For example,

- OsmoBSC needs to know the MSC’s point-code, to be able to establish the A-interface.
- OsmoHNBGW needs to know the MSC’s point-code, to be able to establish the IuCS-interface.
- OsmoHNBGW needs to know the SGSN’s point-code, to be able to establish the IuPS-interface.

To maintain remote SCCP addresses, each *cs7* instance maintains an SCCP address book:

```
cs7 instance 0
  sccp-address remote-pc-example
  point-code 1.23.1
```

This address book entry on its own has no effect. It is typically referenced by specific configuration items depending on the individual programs.

Examples:

- An OsmoBSC configures the MSC’s remote SCCP address:
**8.4 Point-Code Format**

Point-codes can be represented in various formats. For details, see OsmoSTP manual, chapter “Point Codes”.

By default, Osmocom uses a point-code representation of 3.8.3, i.e. first digit of 3 bit, second digit of 8 bit, and third digit of 3 bit.

```
cs7 instance 0
  point-code format 3 8 3
  point-code 0.23.1
```

Often, point-codes are also represented as a single decimal number:

```
cs7 instance 0
  point-code format 24
  point-code 185
```

It is also possible to use a dash as delimiter.

```
cs7 instance 0
  point-code delimiter dash
  point-code 0-23-1
```
8.5 AS and ASP

Each CNI program needs at least one Application Server as and one Application Server Process asp configured on its cs7 to be able to communicate on SCCP/M3UA. An asp needs to be part of at least one as. For details, see the OsmoSTP manual, chapters "Application Server" and "Application Server Process".

In Osmocom’s cs7, any amount of as and asp can be configured by name, and an as references the asp entries belonging to it by their names.

In a simple/minimal Osmocom setup, an Osmocom CNI program would have exactly one as with one asp.

For example:

```plaintext
cs7 instance 0
asp my-asp 2905 0 m3ua
  # where to reach the STP:
  remote-ip 127.0.0.1
  sctp-role client
  as my-as m3ua
  asp my-asp
```

In Osmocom CNI programs, it is possible to omit the as and/or asp entries, which the program will then attempt to configure automatically.

When configuring both as and asp manually, make sure to link them by name. For example, the following configuration will fail, because as and asp are not linked:

```plaintext
cs7 instance 0
asp my-asp 2905 0 m3ua
  remote-ip 127.0.0.1
  as my-as m3ua
  routing-key 2 0.23.1
```

To fix above config, link the asp to an as by adding asp my-asp:

```plaintext
cs7 instance 0
asp my-asp 2905 0 m3ua
  remote-ip 127.0.0.1
  as my-as m3ua
  asp my-asp
  routing-key 2 0.23.1
```

8.6 Subsystem Number (SSN)

Osmocom CNI programs typically route SCCP/M3UA messages by PC+SSN: each ASP, having a given SCCP address, receives messages for one or more specific subsystems, identified by a Subsystem Number (SSN).

For example, the A-interface between BSC and MSC uses SSN = BSSAP (254). In Osmocom programs, SSNs do not need to be configured; they implicitly, naturally relate to the interfaces that a program implements.

For example, OsmoBSC takes the configured remote MSC’s SCCP address and adds the SSN = BSSAP to it in order to contact the MSC’s A-interface. To receive A-interface messages from the MSC, OsmoBSC subscribes a local user for this SSN on the ASP.
8.7 Routing Context / Routing Key

In SCCP/M3UA, messages can be routed by various Routing Indicators (PC+SSN, PC, GT, ...). Osmocom CNI programs typically use PC+SSN as Routing Indicator.

On the SG (for example OsmoSTP), each ASP’s distinct Routing Indicator needs to be indexed by a distinct Routing Context (a simple index number scoped per SG), to forward M3UA to the correct peer.

The Osmocom SG implementation employs Routing Key Management (RKM, see OsmoSTP manual) to automatically determine a distinct Routing Context index for each connected ASP. Routing Contexts can also be configured manually — some non-Osmocom SG implementations require this.

Each Routing Context is associated with a Routing Indicator and address; this association is called a Routing Key.

For example, to configure an OsmoBSC with a local point-code of 1.23.3 to receive M3UA with Routing Context of 2 and RI=PC:

```
cs7 instance 0
  point-code 1.23.3
  as my-as m3ua
  routing-key 2 1.23.3
```

Osmocom programs so far implement Routing Keys by Destination Point Code (DPC), plus optional Subsystem Number (SSN) and/or Service Indicator (SI):

```
routing-key RCONTEXT DPC
routing-key RCONTEXT DPC si (aal2|bicc|b-isup|h248|isup|sat-isup|sccp|tup)
routing-key RCONTEXT DPC ssn SSN
routing-key RCONTEXT DPC si (aal2|bicc|b-isup|h248|isup|sat-isup|sccp|tup) ssn SSN
```

8.7.1 M3UA without Routing Context IE / Routing Context 0

As per the M3UA specification, the use of the routing context IE is optional as long as there is only one AS within an ASP. As soon as there are multiple different AS within one ASP, the routing context IE is mandatory, as it is the only clue to differentiate which of the ASs a given message belongs to.

In the Osmocom M3UA implementation, it is generally assumed that a routing context IE is always used, for the sake of clarity. However, the routing context ID of 0 has the special meaning of do not encode a routing context IE on transmit.

So if you configure an application like OsmoBSC to use routing context 0, then no routing context IE will be included in outbound M3UA messages.

This special interpretation of 0 within the Osmocom M3UA implementation however means that we can not represent M3UA with a routing context IE that actually contains 0 as a numeric identifier.

So you only have the following options: * Using M3UA with routing context (1..N) * Using M3UA without routing context (0)

9 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
   Circiut-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

dvnixload
   Tool to program UBL and the Bootloader on a sysmoBTS

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

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

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 COM munications; 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

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

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

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

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

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

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

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

RF
Radio Frequency

RFM
Remote File Management; Ability to remotely manage (write, read) files on a SIM/USIM card
Roaming
Procedure in which a subscriber of one network is using the radio network of another network, often in different countries; in some countries national roaming exists

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

RR
Radio Resources; Part of the GSM Layer 3 Protocol

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

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

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

SCCP
Signalling 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

SS7
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; IETF RFC 4250 [ietf-rfc4251] to 4254

SSN
Sub-System Number; identifies a given SCCP Service such as MSC, HLR
STP  
Signaling Transfer Point; A Router in SS7 Networks

SUA  
SCCP User Adaptation; a SIGTRAN Variant ([RFC 3868](https://www.rfc-editor.org/rfc/rfc3868))

**syslog**  
System logging service of UNIX-like operating systems

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

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

TCP  
Transmission Control Protocol; ([IETF RFC 793](https://tools.ietf.org/html/rfc793))

TFTP  
Trivial File Transfer Protocol; ([IETF RFC 1350](https://tools.ietf.org/html/rfc1350))

TOS  
Type Of Service; bit-field in IPv4 header, now re-used as DSCP ([IETF RFC 791](https://tools.ietf.org/html/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  

UICC  
Universal Integrated Chip Card; A smart card according to [ETSI TR 102 216](https://www.etsi.org/deliver/etsi_tr/102200_102299/102216/01.01.01_60/tr102216v010101p.pdf)

**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. *100 → 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/specifications/38-series/38.018)) 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 [ieee-802.1q])

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.

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<th>Port Number</th>
<th>Purpose</th>
<th>Software</th>
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</tr>
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<td></td>
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<td>A-bis/IP RSL</td>
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<td>Control Interface</td>
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</tr>
<tr>
<td>TCP 4237</td>
<td>telnet (VTY)</td>
<td></td>
<td>osmo-trx</td>
</tr>
<tr>
<td>TCP 4238</td>
<td>Control Interface</td>
<td></td>
<td>osmo-bts</td>
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<tr>
<td>TCP 4239</td>
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<td>osmo-stp</td>
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<td>TCP 4240</td>
<td>telnet (VTY)</td>
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<td>osmo-pcu</td>
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<td>TCP 4241</td>
<td>telnet (VTY)</td>
<td></td>
<td>osmo-bts</td>
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<td>TCP 4242</td>
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<td>telnet (VTY)</td>
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<td>telnet (VTY)</td>
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<td>telnet (VTY)</td>
<td></td>
<td>osmo-nitb, osmo-bsc</td>
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<td>Control Interface</td>
<td></td>
<td>osmo-bsc_nat</td>
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<td>TCP 4251</td>
<td>Control Interface</td>
<td></td>
<td>osmo-sgsn</td>
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<tr>
<td>TCP 4252</td>
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<td>systmbts-mgr</td>
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<td>TCP 4253</td>
<td>telnet (VTY)</td>
<td></td>
<td>osmo-gthub</td>
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<td>TCP 4254</td>
<td>telnet (VTY)</td>
<td></td>
<td>osmo-msc</td>
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<td>TCP 4255</td>
<td>Control Interface</td>
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<td>osmo-msc</td>
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<td>TCP 4256</td>
<td>telnet (VTY)</td>
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<td>osmo-sip-connector</td>
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<td>TCP 4257</td>
<td>Control Interface</td>
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<td>TCP 4258</td>
<td>telnet (VTY)</td>
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<td>osmo-hlr</td>
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<td>TCP 4259</td>
<td>Control Interface</td>
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<td>osmo-hlr</td>
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<td>L4 Protocol</td>
<td>Port Number</td>
<td>Purpose</td>
<td>Software</td>
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<td>-------------</td>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>TCP</td>
<td>4260</td>
<td>telnet (VTY)</td>
<td>osmo-ggsn</td>
</tr>
<tr>
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