# sysmocom

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# OsmoGbProxy User Manual

by Harald Welte and Daniel Willmann

DRAFT

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The Asciidoc source code of this manual can be found at https://git.osmocom.org/osmo-sgsn/doc/

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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
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- sysmocom, for hosting and funding a lot of Osmocom development, the annual Osmocom Developer Conference and releasing this manual.

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- 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/operating 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.

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## 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.

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

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

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#### 2.4.5 Documentation License

Please see Appendix C for further information.

# 3 Introduction

## 3.1 Required Skills

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

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

If you do not share an existing background in GSM network architecture 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



**Important**
If you have used an earlier version of OsmoGbProxy please note that support for various features such as PLMN/APN patching, support for a secondary SGSN has been removed.

### 4.1 About OsmoGbProxy

OsmoGbProxy is the Osmocom proxy for the 3GPP Gb interface. The Gb interface is defined by 3GPP as the protocol between the BSS and the SGSN inside the 2G/2.5G/2.75G packet switched network domain.

As Osmocom implements a BTS-colocated PCU, there are potentially many Gb interface connections between all those many PCUs in the network and the SGSN. This can be cumbersome to configure/maintain at the SGSN side.

OsmoGbProxy aggregates many PCU-facing Gb connections into one Gb connection to the SGSN. This is achieved by

- maintaining separate NS-VCs on the PCU side and on the SGSN side
- more or less transparently routing BSSGP peer-to-peer Virtual Circuits (BVCs) through the proxy
- having some special handling for the signaling BVC (BVCI=0) which is shared among all the PCUs connected to the proxy

### 4.2 Data Model

#### 4.2.1 gbproxy_config

This contains the parsed configuration of the OsmoGbProxy.

#### 4.2.2 gbproxy_nse

The remote NS-entity that the proxy interacts with. Includes information about:

- the [unique] NSEI of the peer
- the Routeing Area (RA) of the peer
- which side this NSE is facing - SGSN or BSS
- the list of BVCs in this NSE

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#### 4.2.3 gbproxy_bvc

A ptp-BVC on an NSE

- the BVCI of this BVC
- the routing area of this BVC
- the BVC state machine

#### 4.2.4 gbproxy_cell

This contains a view of the cell and its associated BVCs

- the unique BVCI of this cell
- the routing area of this cell
- one bss-side BVC
- one BVC per SGSN in the pool

#### 4.2.5 gbproxy_sgsn

Represents one SGSN in the pool. Contains:

- the NSE belonging to this SGSN
- a (configurable) name of the SGSN
- pool-related configuration of the SGSNs

#### 4.2.6 IMSI cache

In order to route messages to the correct BSS or SGSN OsmoGbProxy sometimes needs to cache where messages came from.

In BSS→SGSN direction the IMSI-cache is needed for

- paging ps reject
- dummy paging response

when SGSN-pooling is enabled and multiple SGSNs are configured. The IMSI contained in a paging ps or dummy paging message is cached together with the originating SGSN/NSE. The answer, which also contains the IMSI, is then routed back to the original SGSN.

#### 4.2.7 TLLI cache

In SGSN→BSS direction OsmoGbProxy needs a TLLI cache to correctly route the following messages:

- suspend ack/nack
- resume ack/nack

Suspend/resume are sent over the signalling BVC to the SGSN. OsmoGbProxy saves the TLLI→NSE association in the TLLI cache and routes the ack/nack back to the signalling BVC of the originating NSE.

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# 5 Proxy details

## 5.1 BVC handling

This section describes in more detail how BVCs are handled in OsmoGbProxy

If a BSS connects to OsmoGbProxy while the SGSN is not available it will acknowledge the BVC RESET on the signalling BVC, but ignore other messages (especially any PTP BVC RESET).

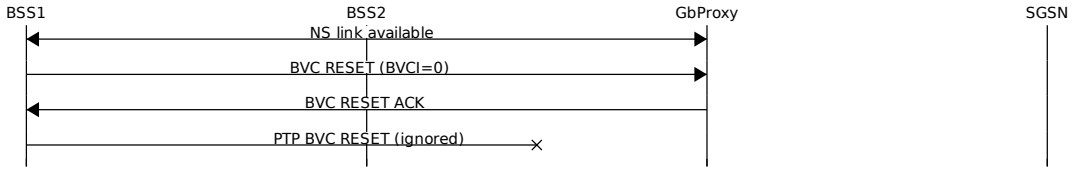



Figure 1: BSS connects to OsmoGbProxy

As soon as the SGSN is reachable through NS OsmoGbProxy will send a BVC RESET to the signalling BVC towards the SGSN. After that completes it will reset the signalling BVC of all BSS connections. At this point the BSS will send a BVC RESET for its PTP BVCs which will be forwarded to the SGSN, similarly the PTP BVC RESET ACK from the SGSN will be sent back to the BSS.

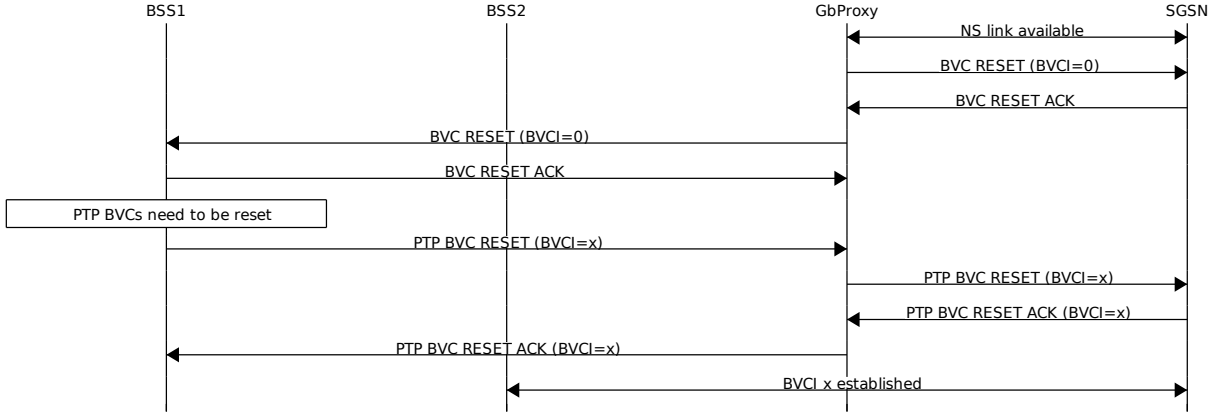



Figure 2: SGSN connection to OsmoGbProxy

The communication on the PTP BVC will then be forwarded between the BSS and the SGSN.

If a BSS connects while the SGSN is up the PTP BVC RESET will directly be forwarded.

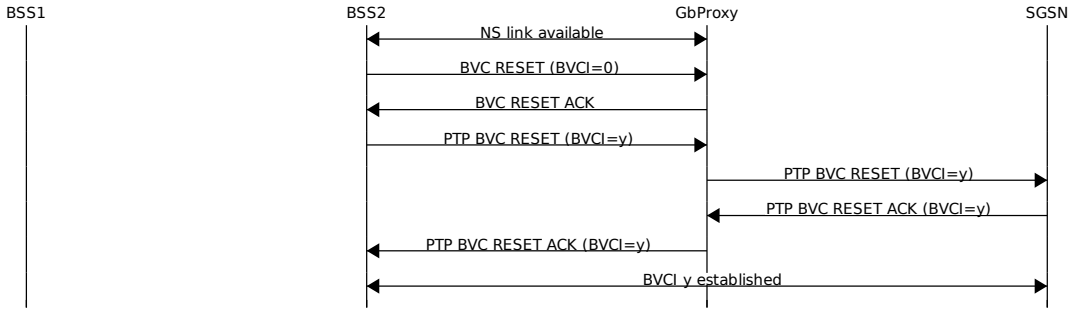



Figure 3: BSS connects to OsmoGbProxy

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If OsmoGbProxy looses the connection to the SGSN it will reset the signalling BVC of all BSS connections. This ensures that the BSS will not send traffic over a PTP BVC before its reset procedure has been completed.

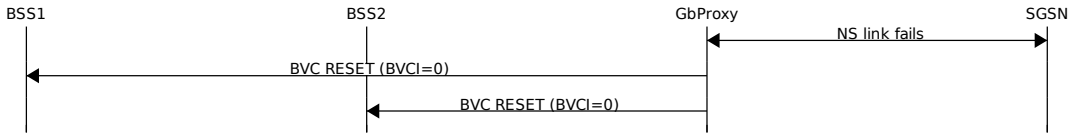



Figure 4: SGSN connection fails

When the connection to the SGSN is eventually restored the signalling BVC between OsmoGbProxy and SGSN will be reset.

After that completes OsmoGbProxy will reset the signalling BVC on all BSS NS connections and forward the PTP BVC RESET messages.

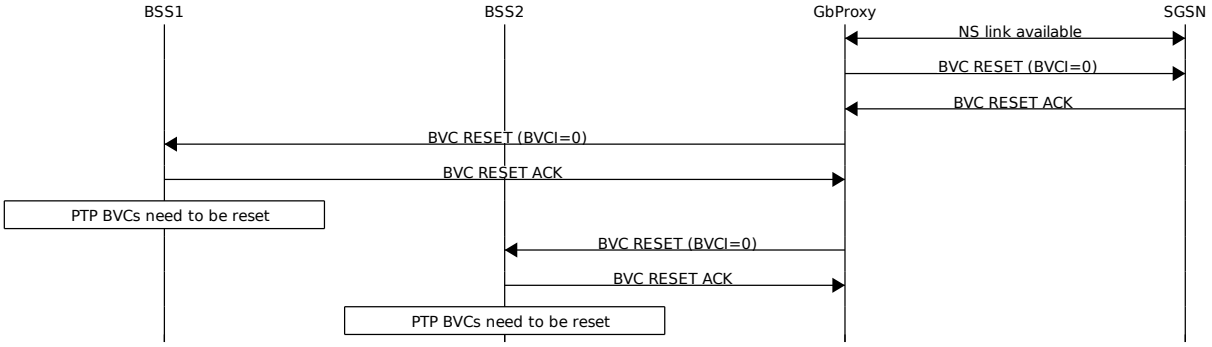



Figure 5: SGSN connection restored

# 6 Running OsmoGbProxy

The OsmoGbProxy executable (`osmo-gbproxy`) offers the following command-line options:

## 6.1 SYNOPSIS

**osmo-gbproxy** [-hl-V] [-d *DBGMASK*] [-D] [-c *CONFIGFILE*] [-s] [-e *LOGLEVEL*] [-T]

## 6.2 OPTIONS

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

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

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

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

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

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

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

**-T, --timestamp**
Enable prefixing each log line on stderr with a timestamp. This has mostly been deprecated by VTY based logging configuration, see Section 9 for more information.

# 7 Control interface

The actual protocol is described in Section 13, the variables common to all programs using it are described in Section 13.2. Here we describe variables specific to OsmoGbProxy.

Table 1: Variables available over control interface

| Name | Access | Trap | Value | Comment |
|---|---|---|---|---|
| nsvc-state | RO | No | "<nsei>,<nsvci>,<local-alive>,<local-blocked>,<remote-role>,<remote-alive>,<remote-blocked>" | See Section 7.1 for details. |
| gbproxy-state | RO | No | "<nsei>,<bvci>,<mcc>,<mnc>,<lac>,<rac>,<blocked>" | See Section 7.2 for details. |
| number-of-peers | RO | No | "<num-of-bss>" | Count of concurrent BSS(BTS) peers. |

## 7.1 nsvc-state

Return the list of active NS-VCs (NS Virtual Circuits), including information on the key parameters, such as NSEI, NSVCI and the local + remote ALIVE and BLOCKED state.

## 7.2 gbproxy-state

Return the list of active Peers, including information on the key parameters, such as NSEI, BVCI, and the MCC-MNC-LAC-RAC of the attached BSS, as well as the overall state (BLOCKED or UNBLOCKED).

# 8 The Osmocom VTY Interface

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

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

The interactive telnet VTY is used to

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

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

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

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

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

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

Table 2: VTY Parameter Patterns

| Pattern | Example | Explanation |
|---|---|---|
| `A.B.C.D` | `127.0.0.1` | An IPv4 address |
| `A.B.C.D/M` | `192.168.1.0/24` | An IPv4 address and mask |
| `X:X::X:X` | `::1` | An IPv6 address |
| `X:X::X:X/M` | `::1/128` | An IPv6 address and mask |
| `TEXT` | `example01` | A single string without any spaces, tabs |
| `.TEXT` | `Some information` | A line of text |
| `(OptionA\|OptionB\|OptionC)` | `OptionA` | A choice between a list of available options |
| `<0-10>` | `5` | A number from a range |

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## 8.1 Accessing the telnet VTY

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

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

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



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

## 8.2 VTY Nodes

The VTY by default has the following minimal nodes:

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

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

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

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

## 8.3 Interactive help

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

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

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#### 8.3.1 The question-mark (?) command

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

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

**Example: Typing ? at start of OsmoMSC prompt**

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

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

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

**Example: Typing ? after a partial command**

```
OsmoMSC> show ❶
  version           Displays program version
  online-help       Online help
  history           Display the session command history
  cs7               ITU-T Signaling System 7
  logging           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
  statistics        Display network statistics
  sms-queue         Display SMSqueue statistics
  smpp           SMPP Interface
```

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

You may pick the `bsc` object and type `?` again:

**Example: Typing ? after show bsc**

```
OsmoMSC> show bsc
  <cr>
```

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

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### 8.3.2 TAB completion

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

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

```
OsmoMSC> s❶
show       sms        subscriber
```

❶ Type `<tab>` here.

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

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

```
OsmoMSC> show ❶
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
```

❶ Type `<tab>` here.

### 8.3.3 The `list` command

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

**Example: Typing list at start of 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 extended-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]
```

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```
  logging set-log-mask MASK
  logging level (rll|cc|mm|rr|mncc|pag|msc|mgcp|ho|db|ref|ctrl|smpp|ranap|vlr|iucs|bssap| ↩
      sgs|lglobal|llapd|linp|lmux|lmi|lmib|lsms|lctrl|lgtp|lstats|lgsup|loap|lss7|lsccp|lsua ↩
      |lm3ua|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 asciidoc 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|sdcch)
  subscriber (msisdn|extension|imsi|tmsi|id) ID silent-call stop
  subscriber (msisdn|extension|imsi|tmsi|id) ID ussd-notify (0|1|2) .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
```

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```
  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
```

#### 8.3.4 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 implemets 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)
```

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```
  . ...  write terminal
  . ...  write file [PATH]
  . ...  write memory
  . ...  write
  . ...  show running-config ❶
  . ...  exit
  . ...  end
  . o..  type (unknown|bs11|nanobts|rbs2000|nokia_site|sysmobts) ❷
  . ...  description .TEXT
  . ...  no description
  . o..  band BAND
  . .r.  cell_identity <0-65535> ❸
  . .r.  dtx uplink [force]
  . .r.  dtx downlink
  . .r.  no dtx uplink
  . .r.  no dtx downlink
  . .r.  location_area_code <0-65535>
  . o..  base_station_id_code <0-63>
  . o..  ipa unit-id <0-65534> <0-255>
  . o..  ipa rsl-ip A.B.C.D
  . o..  nokia_site skip-reset (0|1)
  ! ...  nokia_site no-local-rel-conf (0|1) ❹
  ! ...  nokia_site bts-reset-timer  <15-100> ❺
```

❶ This command has no attributes assigned.

❷ This command applies on A-bis OML link (re)establishment.

❸ This command applies on A-bis RSL link (re)establishment.

❹, ❺ 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.

### 8.3.5 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**

```
OsmoBSC> enable expert-mode ❶
OsmoBSC# list with-flags
  ...
  ^   bts <0-255> (activate-all-lchan|deactivate-all-lchan) ❷
  ^   bts <0-255> trx <0-255> (activate-all-lchan|deactivate-all-lchan) ❸
```

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```
.   bts <0-255> trx <0-255> timeslot <0-7> sub-slot <0-7> mdcx A.B.C.D <0-65535> ❹
^   bts <0-255> trx <0-255> timeslot <0-7> sub-slot <0-7> (borken|unused) ❺
.   bts <0-255> trx <0-255> timeslot <0-7> sub-slot <0-7> handover <0-255> ❻
.   bts <0-255> trx <0-255> timeslot <0-7> sub-slot <0-7> assignment ❼
.   bts <0-255> smscb-command (normal|schedule|default) <1-4> HEXSTRING ❽
...
```

❶ This command enables the *expert* mode.

❷, ❸, ❺ This is a hidden command (only shown in the *expert* mode).

❹, ❻, ❼, ❽ This is a regular command that is always shown regardless of the mode.

# 9 libosmocore Logging System

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

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

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

The logging system is composed of

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

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

## 9.1 Log categories

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

## 9.2 Log levels

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

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

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

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

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

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

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

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

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

Afterwards you can adjust specific categories as usual.

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

## 9.3 Log printing options

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

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

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

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

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

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

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

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

## 9.4 Log filters

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

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

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

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

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## 9.5 Log targets

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

### 9.5.1 Logging to the VTY

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

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

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

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

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

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

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

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

### 9.5.2 Logging to the ring buffer

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

It's configured as follows:

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

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

### 9.5.3 Logging via gsmtap

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

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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.

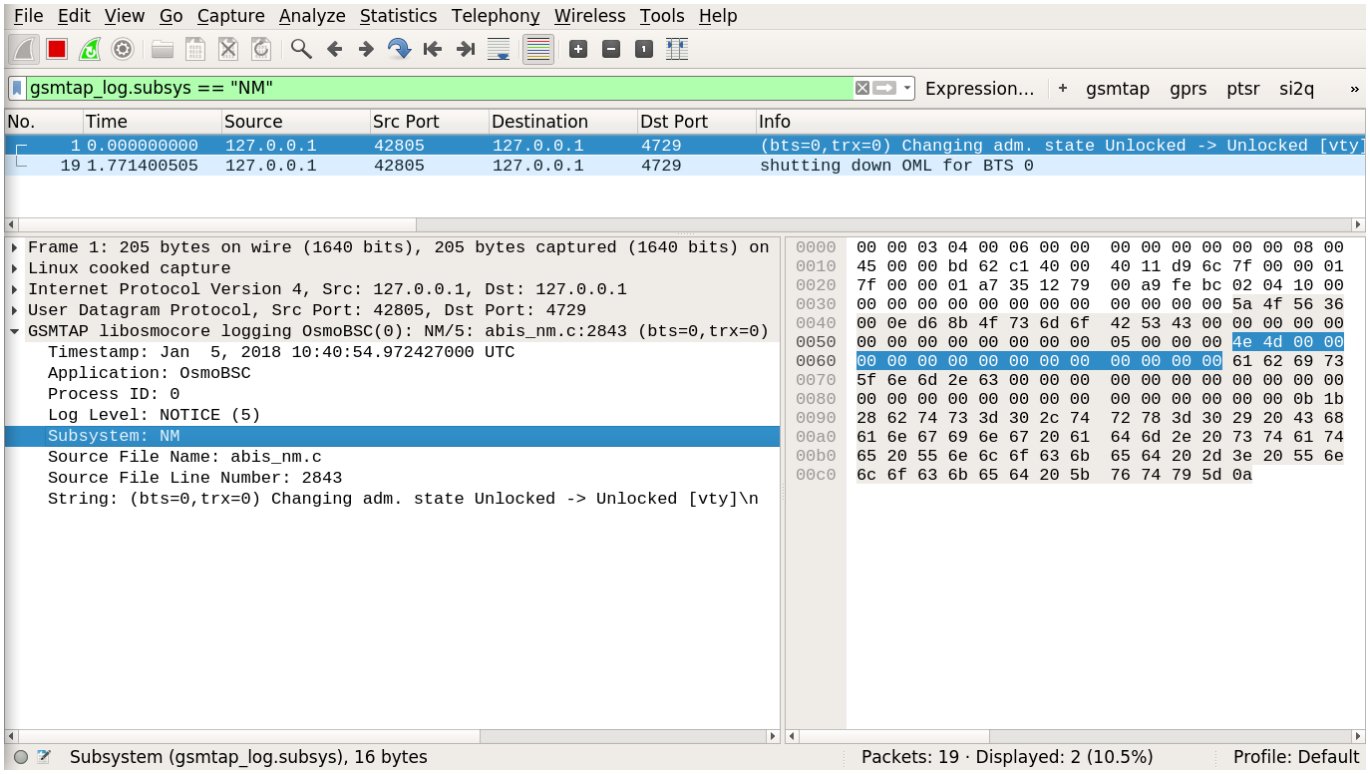



Figure 6: Wireshark with logs delivered over GSMTAP

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

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

#### 9.5.4 Logging to a file

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

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

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

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

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

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

#### 9.5.5 Logging to syslog

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

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

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

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

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

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### 9.5.6 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.

[1] https://www.freedesktop.org/software/systemd/man/systemd-journald.service.html [2] https://www.freedesktop.org/software/-systemd/man/systemd.journal-fields.html

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 ❶
 logging filter all 1
 logging level set-all notice
```

❶ `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 ❶
 logging filter all 1
 logging print file basename
 logging print category-hex 0
 logging print category 1
 logging print level 1
 logging timestamp 0 ❷
 logging color 1 ❸
 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*.

#### 9.5.7 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)#
```

## 10 Configuring OsmoGbProxy

OsmoGbProxy requires very little configuration, most of it being the configuration of the NS links. Most config options specific to OsmoGbProxy are related to SGSN pooling and telling the proxy which NSE(s) it should use to talk to the SGSN(s).

The following config snippets assume the SGSN(s) (NSEI 101 and 102) are using IP-SNS and listen on 10.0.1.1:23000 and 10.0.1.2:23000 respectively.

### 10.1 Configure SGSN(s)

Configuration of a single (non-pooling) SGSN is rather simple.

**Example: SGSN configuration example**

```
sgsn 101 ❶
 name Main SGSN ❷
sgsn 102
ns
 bind udp sgsn-side
  listen 10.0.0.1 23000 ❸
 nse 101 ❹
  ip-sns-bind sgsn-side ❺
  ip-sns-remote 10.0.1.1 23000 ❻
 nse 102
  ip-sns-bind sgsn-side
  ip-sns-remote 10.0.1.2 23000
```

1. Each SGSN is identified by its NSEI (same as in the NS configuration)
2. An SGSN can optionally have a name. If none is set a default name will be used.
3. Define IP/port from which to connect
4. Define an NSE with NSEI
5. Use this bind to connect from
6. Use IP-SNS to connect to the SGSN

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## 10.2 Configure a socket for BSS

The following configuration shows how to accept arbitrary BSS-NSE

**Example: NS configuration example (NS)**

```
ns
 bind udp bss-side ❶
  listen 10.0.0.100 23000
  accept-dynamic-ip-sns ❷
 ip-sns-default bind bss-side ❸
```

❶ Define bind with IP/port for the BSS

❷ Allow BSS with dynamic NSE to connect to this bind

❸ Use this bind as default for dynamic NSE

## 10.3 Checking OsmoGbProxy state

The VTY interface (see Section 8) offers you commands to inspect the state of OsmoGbProxy. FIXME mention/link to NS VTY chapter

**Example: Check SGSN-side BVCs**

```
OsmoGbProxy# show gbproxy bvc sgsn ❶
NSEI     1, SIG-BVCI     0 [UNBLOCKED] ❷
NSEI     1, PTP-BVCI  1234, RAI 001-01-1234-0 [UNBLOCKED] ❸
NSEI     1, PTP-BVCI  1235, RAI 001-01-1235-0 [BLOCKED] ❹
```

❶ Show the BVCs towards the SGSN-side

❷ A signalling BVC is required before PTP-BVCs can be established

❸ For PTP-BVCs show the BVCI and RAI that was sent during the RESET procedure

❹ A BVC on the SGSN-side can be blocked either because the BSS blocked the PTP-BVC or if the BSS BVC vanished (due to BVC-RESET or NSE failure). Since there is no way to delete a PTP-BVC it will stay until the SIG-BVC on that NSE is reset.

**Example: Check BSS-side BVCs**

```
OsmoGbProxy# show gbproxy bvc bss ❶
NSEI  1001, SIG-BVCI     0 [UNBLOCKED]
NSEI  1001, PTP-BVCI  1234, RAI 001-01-1234-0 [UNBLOCKED] ❷
NSEI  1002, SIG-BVCI     0 [UNBLOCKED]
NSEI  1002, PTP-BVCI  1235, RAI 001-01-1235-0 [BLOCKED]
```

❶ Show the BVCs towards the BSS-side

❷ The information displayed is the same as for the SGSN-side

**Example: Show cell information**

```
OsmoGbProxy# show gbproxy cell
BVCI  1234 RAI 001-01-1234-0 CID  1234: BSS NSEI  1001, SGSN NSEI     1 ❶
BVCI  1235 RAI 001-01-1235-0 CID  1235: BSS NSEI  1002, SGSN NSEI     1
BVCI  1236 RAI 001-01-1236-0 CID  1236: BSS NSEI  1003, SGSN NSEI     1     2 ❷
BVCI  1237 RAI 001-01-1237-0 CID  1237: BSS NSEI  <none>, SGSN NSEI <none> ❸
```

❶ Show cell information (BVCI, RAI)

❷ When multiple SGSNs are connected (SGSN pooling) more than one NSEI is shown

❸ If the BSS or SGSN side of a cell is currently disconnected none is shown instead of the NSEI

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# 11 SGSN Pooling

SGSN pooling is described in 3GPP TS 23.236 [3gpp-ts-23-236], and is supported by OsmoGbProxy since early 2021.

The aim of SGSN pooling is to distribute load from a BSS across multiple SGSNs, which are equivalent and redundant infrastructure for the same core network.

The main mechanism for SGSN pooling is the TLLI/P-TMSI, which an SGSN hands out to its attached subscribers. Typically 10 bits of the P-TMSI are designated as a Network Resource Identifier (NRI) that identifies the originating SGSN, and allows OsmoGbProxy to direct a subscriber back to the same SGSN instance that previously negotiated the Attach procedure. Typically, the full NRI value range available is divided into N even ranges, where each SGSN is assigned one NRI range.

Subscribers attaching without a TLLI, or those with unknown NRI value, are evenly distributed across SGSN instances. OsmoGbProxy uses a hash-based approach to distribute load across all connected SGSNs.

A Paging Response from a subscriber is always returned back to whichever SGSN initiated the Paging, regardless of the Mobile Identity used.

Finally, a NULL-NRI is a special NRI value that indicates that the SGSN wishes to offload this subscriber to a different SGSN. A NULL-NRI is an arbitrary NRI value that is chosen distinctly for each PLMN served by a BSS, so that a subscriber can be reassigned within that PLMN. Upon (periodic) Location Updating, an offloading SGSN hands out a NULL-NRI value in the assigned TLLI, along with a non-broadcast LAI. The subscriber will notice the LAI mismatch, and immediately re-attempt the attach using the TLLI containing the NULL-NRI. OsmoGbProxy recognises the NULL-NRI and redirects the subscriber to one of the other SGSNs. A prerequisite for this to work well is that the particular SGSN is previously marked as not accepting new subscribers, in OsmoGbProxy's configuration.

The mechanisms described above make up the NAS node selection function implemented in OsmoGbProxy.

3GPP TS 23.236 also defines that an offloading SGSN hands subscriber information to the newly assigned SGSN, which takes place outside the scope of OsmoGbProxy.

## 11.1 Configuring SGSN Pooling

The NRI ranges assigned to each SGSN must match in the OsmoGbProxy and the SGSN configuration. If inconsistent NRI value ranges are configured, attached subscribers would be redirected to SGSN instances that did not perform the attach, possibly rendering the core network unusable.

### 11.1.1 Connecting Multiple SGSNs

```
! Configure the Network Service
ns
 bind udp sgsn
  listen 10.0.0.1 23000
 nse 1
  ip-sns-bind sgsn
  ip-sns-remote 10.0.1.1 23000
  ip-sns-remote 10.0.1.1 23001
 nse 2
  ip-sns-bind sgsn
  ip-sns-remote 10.0.1.2 23000
 nse 3
  ip-sns-bind sgsn
  ip-sns-remote 10.0.1.3 23000
! configure NRI value ranges
gbproxy
 nri bitlen 10
 nri null add 0
sgsn nsei 1
 name SGSN01
 nri add 1 341
```

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```
sgsn nsei 2
 name SGSN02
 nri add 342 682
sgsn nsei 3
 name SGSN03
 nri add 683 1023
```

#### 11.1.2 NRI Value Bit Length

In OsmGbProxy, the NRI value's bit length is freely configurable from 0 to 15 bits. 3GPP TS 23.236 suggests a typical bit length of 10. Setting the length to 0 disables SGSN pooling, this is also the default. The NRI bit length must be identical across the entire SGSN pool.

Change the NRI value bit length in OsmoGbProxy's VTY configuration like this:

```
gbproxy
 nri bitlen 10
```

In the TMSI bits, regardless of the NRI bit length, the NRI value always starts just after the most significant octet of a TMSI (most significant bit at TMSI's bit 23).

#### 11.1.3 NULL-NRI

Since OsmoGbProxy supports serving only one PLMN, NULL-NRI are configured globally. Even though 3GPP TS 23.236 indicates that there is a single NULL-NRI per PLMN, OsmoGbProxy allows configuring multiple NULL-NRI values.

```
network
 nri null add 0
 nri null add 423
```

#### 11.1.4 Assigning NRI Ranges to SGSNs

Each SGSN configured in OsmoGbProxy must be assigned a distinct NRI value range. Overlapping NRI value ranges will cause failure to serve subscribers.

NRI values are typically configured in ranges, here dividing a 10bit range (0..1023) into three equal ranges, while leaving 0 available to be configured as NULL-NRI:

```
sgsn nsei 1
 nri add 1 341
sgsn nsei 2
 nri add 342 684
sgsn nsei 3
 nri add 685 1023
```

NRI can also be assigned in single values:

```
sgsn nsei 1
 nri add 23
```

Ranges can be constructed arbitrarily by a sequence of `add` and `del` configurations, here a contrived example:

```
sgsn nsei 1
 nri add 0 342
 nri del 23
 nri del 42 235
 nri add 1000 1023
```

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On the VIEW and ENABLE VTY nodes, `show nri all` shows all SGSNs:

```
OsmoGbProxy> show nri all
sgsn nsei 1
 nri add 1 341
sgsn nsei 2
 nri add 342 684
sgsn nsei 3
 nri add 685 1023
```

When configuring overlapping NRI value ranges across SGSNs, the telnet VTY warns about it, and starting OsmoGbProxy with such a configuration will fail:

```
sgsn nsei 1
 nri add 1 511
sgsn nsei 2
 nri add 512 1023
sgsn nsei 3
 nri add 500 555
```

This results in:

```
$ osmo-gbproxy
% Warning: NSE(00003/SGSN): NRI range [500..555] overlaps between NSE 00003 and NSE 00001.  ↩
    For overlaps, NSE 00001 has higher priority than NSE 00003
% Warning: NSE(00003/SGSN): NRI range [500..555] overlaps between NSE 00003 and NSE 00002.  ↩
    For overlaps, NSE 00002 has higher priority than NSE 00003
```

#### 11.1.5 SGSN Offloading

To effectively offload a particular SGSN, it must be marked as no longer taking new subscribers in OsmoGbProxy. This can be achieved in the telnet VTY by:

```
sgsn nsei 1
 no allow-attach
```

This SGSN will, as long as it is connected, continue to serve subscribers already attached to it: those that yield an NRI matching this SGSN, and those that are being paged by this SGSN. But OsmoGbProxy will no longer direct new subscribers to this SGSN.

To re-enable an SGSN for attaching new subscribers:

```
sgsn nsei 1
 allow-attach
```

#### 11.1.6 Traffic allocation

In a SGSN pool, osmo-gbproxy is facing the problem of dividing the downlink capacity of a cell towards the SGSN. The BSS advertises the per-BVC capacity by means of the BSSGP FLOW-CONTROL-BVC messages, but as there are multiple SGSN in a pool, they all have to share / divide that total capacity.

By default, osmo-gbproxy advertises the full capacity to *each* of the SGSN pool members, which results in significant over-provisioning and can lead to overload situations.

The administrator can configure the *percentage* of the overall BSS-advertised capacity that shall be reported to each pool member SGSN using the `pool bvc-flow-control-ratio <1-100>` configuration command.

A setting of 100 means that each pool member is informed of 100% of the BSS side capacity.

A setting of 25 means that each pool member is informed of 25% of the BSS side capacity. This would make most sense in a set-up with four SGSN of equal share.

More complex capacity division schemes are so far not supported by osmo-gbproxy.

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# 12 Gb/NS Network Service

*libosmogb* is part of the libosmocore.git repository and implements the Gb interface protocol stack consisting of the NS and BSSGP layers. It is used in a variety of Osmocom projects, including OsmoSGSN, OsmoPCU and OsmoGbProxy.

**Note**
[3gpp-ts-48-016] specifies Network Service

## 12.1 Gb interface variants

There are multiple variants of the Gb interface. This section tries to provide an overview into what those variants are, how they differ from each other.

The two peers involved in any Gb interface must always be in agreement about the specific Gb interface variant before they are able to connect.

The following variants are supported by Osmocom:

- Gb-over-Frame-Relay over E1/T1
- Gb-over-IP "ip.access style"
- Gb-over IP 3GPP static configuration
- Gb-over-IP 3GPP auto-configuration

### 12.1.1 Gb over Frame Relay over E1/T1

Historically, this is the first Gb interface that was specified as part of GSM Release 97 when GPRS was first introduced.

Like all other terrestrial GSM interfaces, it uses circuit-switched technology from the PDH/ISDN family of systems: E1 or T1 lines as per ITU-T G.703 / G.704.

GSM TS 08.16 and later [3gpp-ts-48-016] specify that Frame Relay (FR) shall be used as transport layer between the E1/T1 bit-stream and the NS-level Gb messages.

Two peer entities such as a GPRS BSS and a SGSN are interconnected by a NS-VCG (Virtual Connection Group) consisting of any number of NS-VCs (Virtual Connections).

Each NS-VC in turn operates over a Frame Relay Permanent Virtual Circuit (PVC), identified by its DLCI (Data Link Connection Identifier).

The protocol stacking is BSSGP/NS/FR/E1.

#### 12.1.1.1 FR Driver Support

The Osmocom NS/FR implementation currently requires the individual Frame Relay Links to be exposed as Linux kernel HDLC net-devices. The Osmocom NS implementation has to be instructed which `hdlcX` network devices it shall use for each NS-VC, and which DLCIs to use on them.

The Linux kernel Frame Relay LMI support (which only implements the user role anyway) is not used. Instead, the ITU-T Q.933 LMI is implemented as part of the Osmocom NS code in libosmogb. Osmocom NS code configures the `hdlcX` device to match the correct mode (fr) and lmi (none). This is equivalent to the user-space command `sethdlc hdlcX fr lmi none`. The net-devices will be also brought *up* by the Osmocom NS code equivalent to `ip link set hdlcX up` command.

As the Osmocom Gb implementation uses AF_PACKET sockets on those `hdlcX` network interfaces, the respective program must be running with `CAP_NET_RAW` capability.

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#### 12.1.2 Gb over Frame Relay encapsulated in GRE/IP

This is a variant of the Gb-over-FR specified above. However, an external router (e.g. certain ancient Cisco routers) is used to take the Frame Relay frames from the physical E1/T1 TDM circuit and wrap them into the GRE encapsulation as per IETF RFC 2784.

**Note**
GRE/IP has been removed from Osmocom NS code.

#### 12.1.3 Gb over IP "ip.access style"

This is a non-standard variant of Gb which is not found in the GSM/3GPP specifications.

It uses an UDP/IP based transport layer, while not yet implementing the IP-SNS that is normally required by a true 3GPP Gb over IP interface described further below. Hence, this variant resembles an intermediate state where a Gb interface originally designed for Frame Relay is used over IP without any of the IP-specific procedures specified by 3GPP.

The major difference to 3GPP Gb over IP specified below are:

- No support for the IP-SNS and its SNS-SIZE, SNS-ADD, SNS-DELETE, SNS-WEIGHT procedures.
- Use of the NS-RESET, NS-BLOCK and NS-UNBLOCK procedures which are normally forbidden over an IP network.

The protocol stacking is BSSGP/NS/UDP/IP.

#### 12.1.4 Gb over IP 3GPP static and auto-configuration

This is the only official, 3GPP-standardized way of speaking a Gb interface over IP based transport.

It features the IP Sub-Network Service (IP-SNS) which allows either static configuration or dynamic configuration. The static configuration requires to specify the NSE and related NS-VC configuration via VTY similiar to Gb-over-FR.

##### 12.1.4.1 Gb over IP 3GPP auto-configuration

The auto-configuration allow to dynamically exchange information about IP endpoints (IP+port tuples) between the Gb interface peers. This means that normally only one initial IP endpoint needs to be configured. All additional IP endpoints and their relative weight for load distribution are then negotiated via the IP-SNS auto-configuration procedure.

The major differences of this true IP based Gb compared to any of the above are:

- No use of the NS-RESET, NS-BLOCK or NS-UNBLOCK procedures.
- Ability to use some NS-VCs only for signaling (data_weight=0) or only for user plane traffic (signaling_weight=0). This helps with SGSNs that have an internal control/user plane separation architecture.

Once the IP endpoints of the peers are known to each other, A full mesh of NS-VCs between all BSS endpoints and all SGSN endpoints is established.

Figure 7 below illustrates a deployment with two IP endpoints on both the BSS (PCU) and the SGSN, as well as the resulting four NS-VCs established between them.

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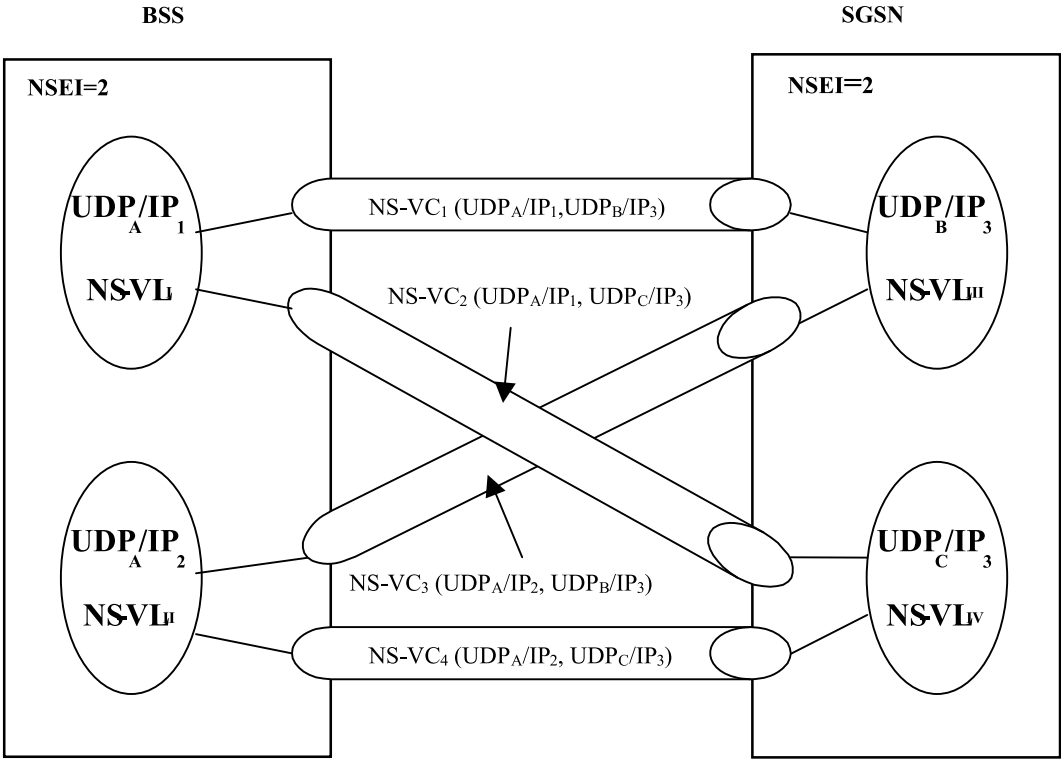



Figure 7: IP sub-network relationship between NS-VCs and NS-VLs (from 3GPP TS 48.016)

The sequence of messages in an IP-SNS enabled Gb interface bring-up can be seen in Figure 8. Here we have a PCU/BSS with a single IP endpoint and a SGSN with two IP endpoints, which results in only two NS-VC being established.

Furthermore, for each of the cells in the BSS/PCU, we can see the BVC-RESET procedure for its corresponding PTP BVC.

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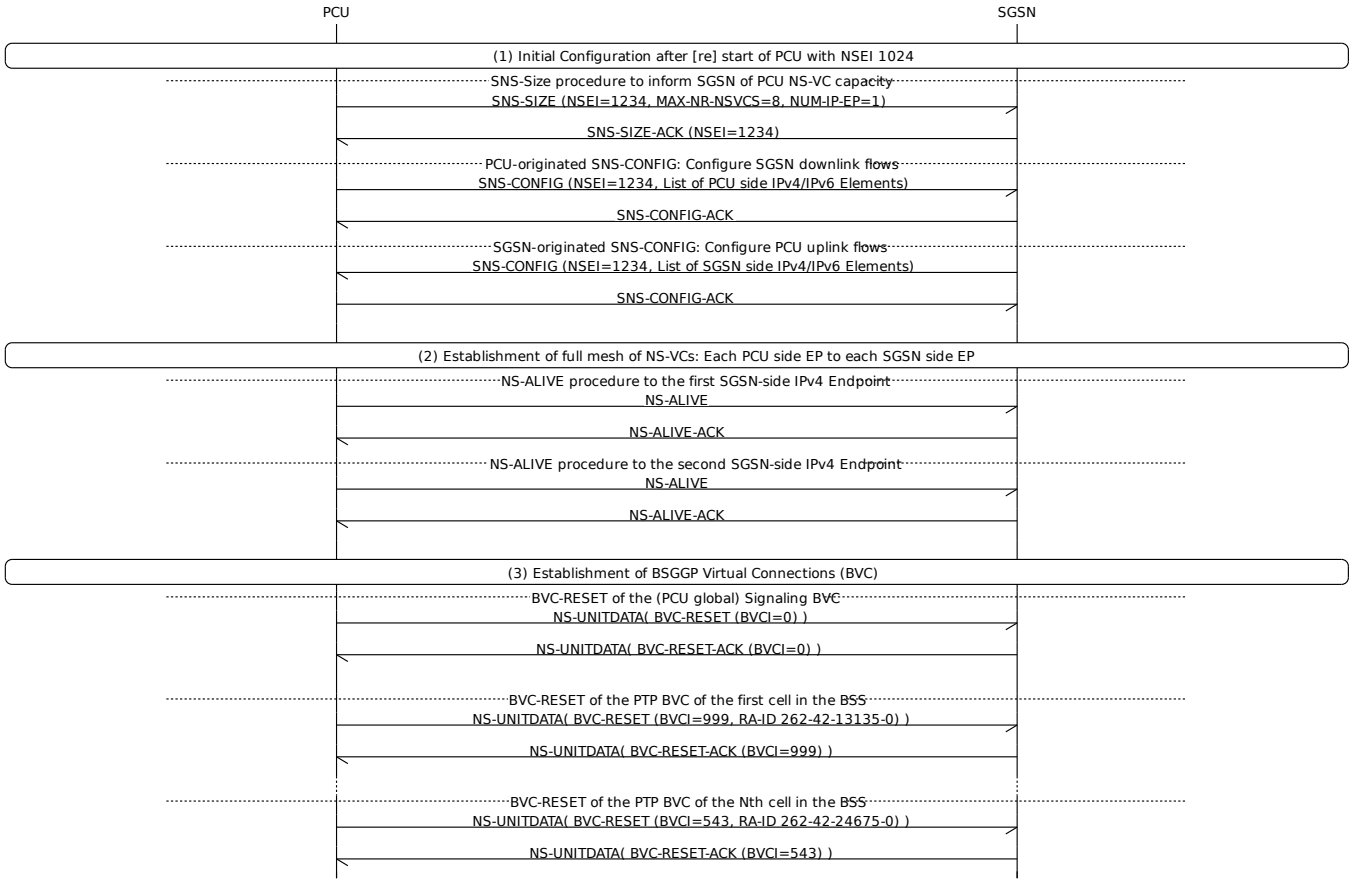



Figure 8: Initialization of Gb interface using IP-SNS procedures

## 12.2 General structure

The general structure of the configuration is split into 3 parts

- binds (NS-VL)
- nse (NS-E)
- timeouts

### 12.2.1 bind (NS-VL)

A bind represent a NS-VL. A bind has a specific type (IP/UDP or FR) and a unique name.

### 12.2.2 NS-E

A NSE node represents a NS Entity. A NSE is either persistent or dynamic. A persistent NSE is configured by VTY. A dynamic NSE is created on-demand without any VTY node. The SGSN/GbProxy creates dynamic NSE when a BSS connects to the SGSN (see accept-ipaccess). The PCU creates a dynamic NSE when it receives the configuration from BTS/BSC.

### 12.2.3 NS-VC

A NS-VC is always bound to a NSE and the bind (NS-VL). The NSVC can be either persistent or dynamic.

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## 12.3 Gb/NS configuration

This section describes the configuration that libosmogb exposes via the VTY and is valid for OsmoSGSN and OsmoGbProxy.

### 12.3.1 Gb over Frame Relay over E1/T1

The Gb over Frame Relay over E1/T1 requires:

- a hdlc interface
- a frame relay role (fr or frnet)
- the DLCI

**Example: Gb over Frame Relay configuration #1**

```
ns
 bind fr sitea1 ❶
  fr hdlc1 frnet ❷
 nse 2001 ❸
  nsvci fr sitea1 dlci 16 nsvci 11
```

❶ a Gb-over-FR bind with the name sitea1

❷ connect the hdlc1 device with the role frnet to sitea1

❸ one NSE (2001) with a single NS-VCI 11 on sitea1 with DLCI 16

**Example: Gb over Frame Relay configuration #2**

```
ns
 bind fr sitea1 ❶
  fr hdlc1 frnet ❷
 bind fr sitea2
  fr hdlc2 frnet
 bind fr sitea3
  fr hdlc3 frnet
 bind fr sitea4
  fr hdlc4 frnet
 bind fr siteb1
  fr hdlc5 frnet
 bind fr siteb2
  fr hdlc6 frnet
 bind fr sitec1
  fr hdlc7 frnet
 bind fr sitec2
  fr hdlc8 frnet
 nse 2001 ❸
  nsvci fr sitea1 dlci 16 nsvci 11
  nsvci fr sitea2 dlci 17 nsvci 12
  nsvci fr sitea3 dlci 18 nsvci 13
  nsvci fr sitea4 dlci 19 nsvci 14
 nse 2002 ❹
  nsvci fr siteb5 dlci 20 nsvci 15
  nsvci fr siteb6 dlci 21 nsvci 16
 nse 2003 ❺
  nsvc fr sitec7 dlci 22 nsvci 17
  nsvc fr sitec8 dlci 23 nsvci 18
```

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1. a Gb-over-FR bind with the name sitea1
2. connect the hdlc1 device with the role frnet to sitea1
3. one NSE (2001) with four NS-VCI (11..14) on sitea1..4 with their respective DLCI
4. another NSE (2002) with two NS-VCI (15..16) on siteb1..2 with their respective DLCI
5. another NSE (2003) with two NS-VCI (17..18) on sitec1..2 with their respective DLCI

#### 12.3.2 Gb over IP "ip.access style"

The Gb over IP "ip.access style" can be used with a dynamic configuration or with a static configuration

The static configuration requires to configure all endpoints on the BSS and SGSN. In contrast the dynamic configuration allows the SGSN to have only a reduced configuration.

##### 12.3.2.1 Gb over IP "ip.access style" dynamic configuration

**Example: Gb over IP/UDP ip.access style dynamic configuration (SGSN)**

```
ns
 bind udp ran1 ❶
  listen 10.100.1.1 23000 ❷
  accept-ipaccess ❸
```

1. create a IP/UDP bind with name ran1
2. bind to 10.100.1.1:23000
3. accept unknown BSS of ip.access style

**Example: Gb over IP/UDP "ip.access style" dynamic configuration (GbProxy as BSS)**

```
ns
 bind udp ran1 ❶
  listen 10.100.0.1 23000 ❷
 nse 1001 ❸
  nsvc ipa ran1 10.100.1.1 23000 nsvci 1001
```

1. create a IP/UDP bind with name ran1
2. bind to 10.100.1.1:23000
3. accept unknown BSS of ip.access style

---

**Note**
The OsmoPCU supports ip.access style Gb/NS but doesn't support this vty configuration because it's receiving the configuration from the BTS/BSC.

---

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#### 12.3.2.2 Gb over IP "ip.access style" static configuration

**Example: Gb over IP/UDP "ip.access style" static configuration (BSS & SGSN)**

```
ns
 bind udp ran1 ❶
  listen 10.100.0.1 23000 ❷
 nse 1001 ❸
  nsvc ipa ran1 10.100.1.1 23000 nsvci 1001
```

❶ create a IP/UDP bind with name ran1

❷ bind to 10.100.0.1:23000

❸ NSE 1001 with nsvc 1001 as ip.access style

**Note**
The OsmoPCU supports "ip.access style" Gb/NS but doesn't support this vty configuration because it's receiving the configuration from the BTS/BSC.

### 12.3.3 Gb over IP 3GPP static configuration

A static IP/UDP configuration without SNS as specified by 3GPP 48.016.

**Example: Gb over IP/UDP static configuration BSS/SGSN**

```
ns
 bind udp ran1 ❶
  listen 10.100.0.1 23000 ❷
 nse 1001 ❸
  nsvc udp ran1 10.100.1.1 23000 signalling-weight 2 data-weight 2
  nsvc udp ran1 10.100.1.2 23000 ❹
```

❶ create a IP/UDP bind with name ran1

❷ bind to 10.100.0.1:23000

❸ add NSE 1001 with 2 NSVC

❹ short configuration with default signalling and data weight of 1

### 12.3.4 Gb over IP 3GPP auto configuration as BSS

IP/UDP auto-configuration with initial endpoints to an SGSN. The auto-configuration will use the first bind to connect to the first endpoint. If this fails Osmocom will iterate over all endpoints and binds to find a working combination.

**Example: Gb over IP/UDP auto-configuration as BSS**

```
ns
 bind udp ran1 ❶
  listen 10.100.0.1 23000 ❷
 bind udp ran2
  listen 10.100.0.2 23000
 bind udp ran3
  listen 10.100.0.3 23000
 nse 1001 ❸
  ip-sns-bind ran1 ❹
  ip-sns-bind ran2
  ip-sns-remote 10.100.1.1 23000 ❺
  ip-sns-remote 10.100.1.2 23000
```

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1. create a IP/UDP bind with name ran1
2. bind to 10.100.0.1:23000
3. add NSE 1001 with 2 initial SNS endpoints
4. add ran1 to the list of available endpoints
5. add 10.100.1.1 as initial endpoint

#### 12.3.5 Gb/NS Timer configuration

The NS protocol features a number of configurable timers.

Table 3: List of configurable NS timers

| | |
|---|---|
| tns-block | (un)blocking timer timeout (secs) |
| tns-block-retries | (un)blocking timer; number of retries |
| tns-reset | reset timer timeout (secs) |
| tns-reset-retries | reset timer; number of retries |
| tns-test | test timer timeout (secs) |
| tns-alive | alive timer timeout (secs) |
| tns-alive-retries | alive timer; number of retries |
| tsns-prov | SNS provision timeout (secs) used by all SNS auto configuration procedures. |
| tsns-size-retries | SNS Size procedure; number of retries |
| tsns-config-retries | SNS Config procedure; number of retries |

All timer can be configured by vty configuration

**Example of timeouts**

```
ns
 timer tns-block 3
 timer tns-block-retries 3
 timer tns-reset 3
 timer tns-reset-retries 3
 timer tns-test 30
 timer tns-alive 3
 timer tns-alive-retries 10
 timer tsns-prov 10
 timer tsns-size-retries 3
 timer tsns-config-retries 3
```

### 12.4 Gb/NS maintenance

This section describes common maintenance procedures.

#### 12.4.1 NSE states

A NSE can have the following states:

NSE STATES

- ALIVE

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- DEAD

For FR, IPA: The NSE is ALIVE if there is at least one NSVC in state UNBLOCKED. For IP-SNS/UDP: The NSE is ALIVE if there is at least one NSVC ALIVE and the sum of all ALIVE NSVCs signalling weights > 0 and data weights > 0.

The state of the NSE is shown by vty.

**show ns**

```
GbProxy# show ns nsei 1234
NSEI 01234: UDP, DEAD ❶
 FSM Instance Name: 'GPRS-NS2-SNS-BSS(NSE01234-SNS)[0x6120000012a0]', ID: 'NSE01234-SNS'
  Log-Level: 'DEBUG', State: 'BSS_SIZE'
  Timer: 1
 Maximum number of remote  NS-VCs: 8192, IPv4 Endpoints: 8192, IPv6 Endpoints: 8192
  1 NS-VC:
   NSVCI none: DISABLED DYNAMIC data_weight=1 sig_weight=1 udp) ↩
       [127.0.0.1]:23000<>[127.0.0.1]:22000
```

❶ NSE state

### 12.4.2 NSVC states

A NSVC can have the following states:

Table 4: nsvc states

| State | transport UNITDATA | Description |
|---|---|---|
| DISABLED | No | Either the transport layer is unavailable (FR) or this NSVC is currently used by IP-SNS dynamic configuration. |
| RESET | No | Sending out RESET PDU and awaiting data. |
| BLOCKED | No* | The NSVC has been BLOCKED. * see 3GPP TS 48.016 § 7.2 exception |
| UNBLOCKED/ALIVE | Yes | The NSVC transport UNITDATA. |
| RECOVERING | No | The NSVC test procedure timed out. NSVC type is a IP-SNS which don't use RESET/BLOCK/UNBLOCK. |

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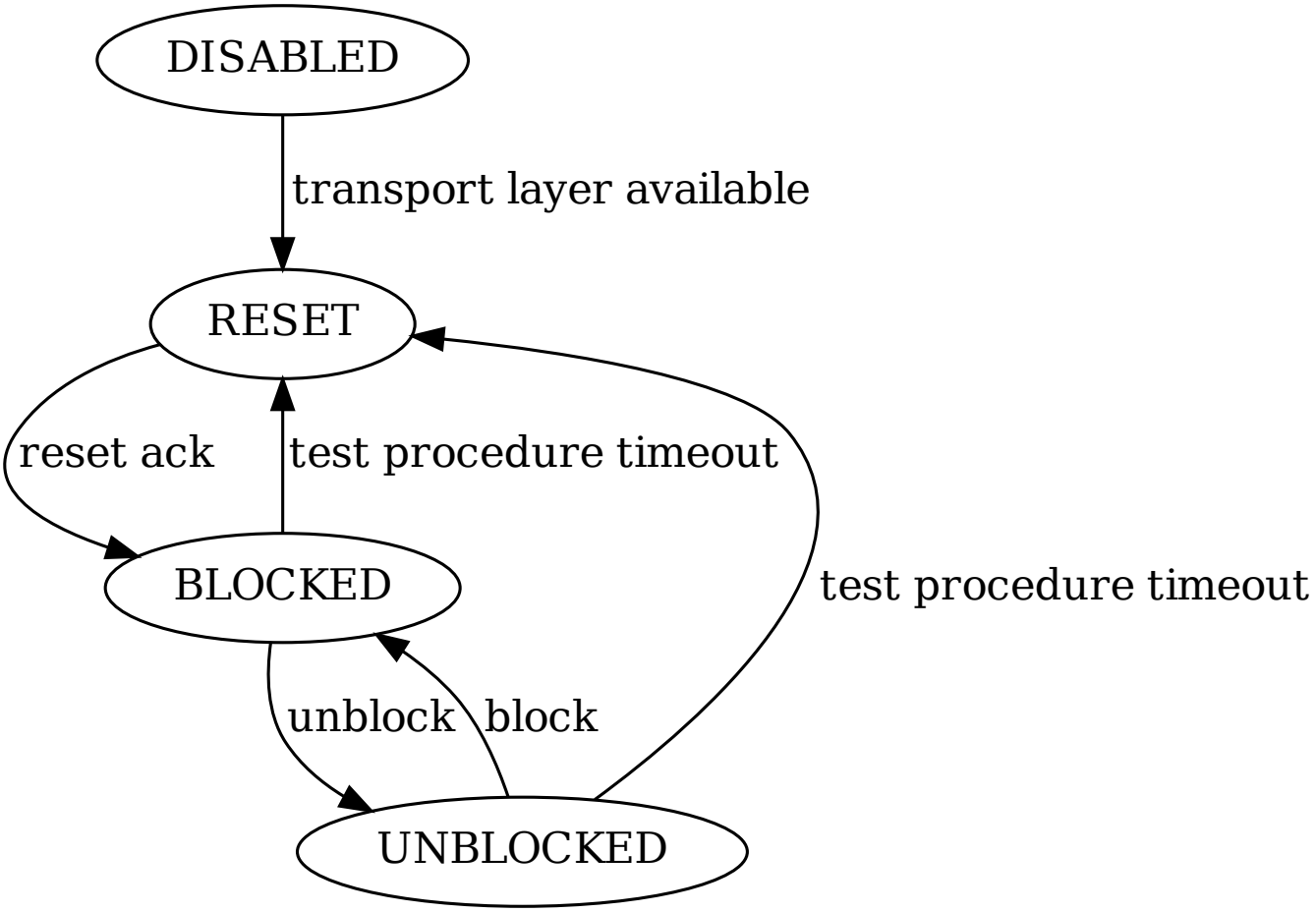



Figure 9: Simplified state diagram for RESET BLOCK UNBLOCK NSVCs

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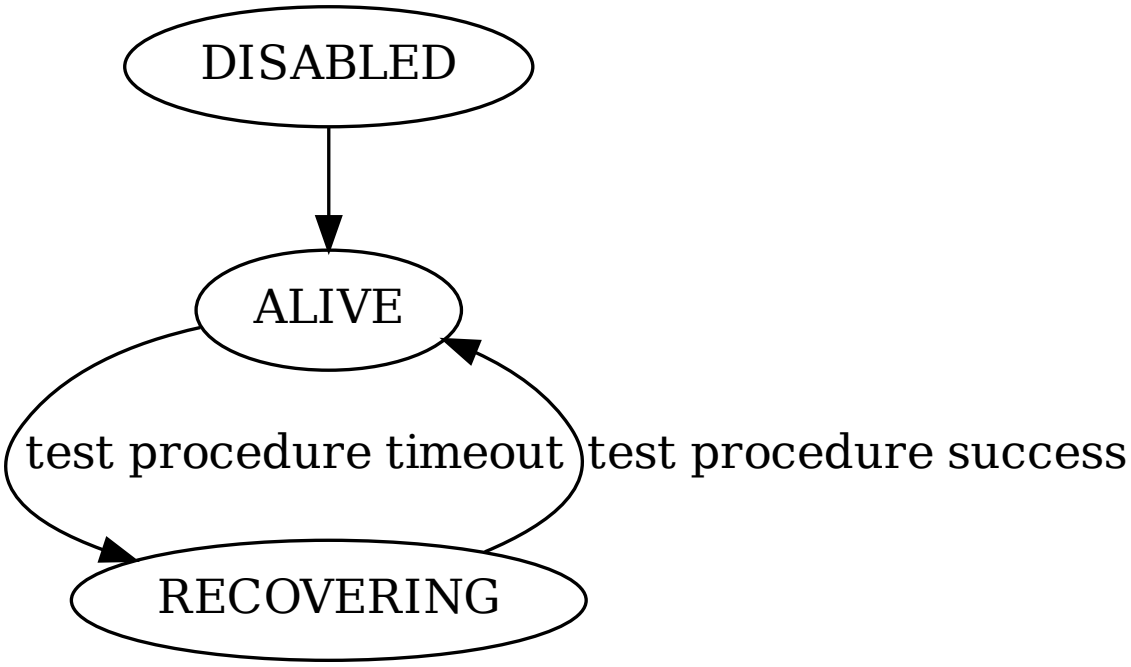



Figure 10: Simplified state diagram for IP-SNS/UDP

#### 12.4.3 Show information of a specific NSE

The NSE 1234 has been configured for as BSS with IP-SNS configuration.

**show ns on a dynamic configured IP-SNS NSE**

```
GbProxy# show ns nsei 1234
NSEI 01234: UDP, DEAD ❶
 FSM Instance Name: 'GPRS-NS2-SNS-BSS(NSE01234-SNS)[0x6120000012a0]', ID: 'NSE01234-SNS'
  Log-Level: 'DEBUG', State: 'BSS_SIZE' ❷
  Timer: 1
 Maximum number of remote  NS-VCs: 8192, IPv4 Endpoints: 8192, IPv6 Endpoints: 8192
  1 NS-VC:
   NSVCI none: DISABLED DYNAMIC data_weight=1 sig_weight=1 udp) ↩
       [127.0.0.1]:23000<>[127.0.0.1]:22000
```

❶ A UDP NSE. A NSE can be ALIVE or DEAD

❷ The SNS state. CONFIGURED and LOCAL_PROCEDURE are ALIVE states

For description of NSE states see Section 12.4.1.

**show ns on a frame relay NSE**

```
OsmoNSdummy# show ns nsei 02001
NSEI 02001: FR, ALIVE ❶
  4 NS-VC:
   NSVCI 00001: DISABLED PERSIST data_weight=1 sig_weight=1 fr)netif: hdlcnet1 dlci: 16 ❷
   NSVCI 00002: DISABLED PERSIST data_weight=1 sig_weight=1 fr)netif: hdlcnet2 dlci: 17 ❸
   NSVCI 00003: DISABLED PERSIST ❹ data_weight=1 sig_weight=1 fr)netif: hdlcnet3 dlci: 18
   NSVCI 00004: DISABLED PERSIST data_weight=1 sig_weight=1 fr)netif: hdlcnet4 dlci: 19
```

❶ A FR NSE. A NSE can be ALIVE or DEAD

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❷ An unblocked NS-VC will be used for data and signalling. data and signalling weight are only relevant for UDP NSVC.

❸ NSVC is still blocked.

❹ A PERSIST NSVC is a configured via VTY.

#### 12.4.4 Blocking a NSVC

**how to block a single NSVC**

```
OsmoNSdummy# show ns nsei 01234
NSEI 01234: UDP, ALIVE since 0d 0h 41m 6s
  2 NS-VC:
   NSVCI 01234: UNBLOCKED PERSIST udp)[127.0.0.1]:23000<1234>[127.0.0.1]:22000 ALIVE since  ↩
       0d 0h 2m 36s
   NSVCI 01235: UNBLOCKED PERSIST udp)[127.0.0.1]:23001<1235>[127.0.0.1]:22001 ALIVE since  ↩
       0d 0h 41m 6s

OsmoNSdummy# nsvc 1234 block
The NS-VC 01234 will be blocked.
OsmoNSdummy# show ns nsei 01234
NSEI 01234: UDP, ALIVE since 0d 0h 42m 7s
  2 NS-VC:
   NSVCI 01234: BLOCKED PERSIST udp)[127.0.0.1]:23000<1234>[127.0.0.1]:22000 DEAD since 0d  ↩
       0h 3m 37s
   NSVCI 01235: UNBLOCKED PERSIST udp)[127.0.0.1]:23001<1235>[127.0.0.1]:22001 ALIVE since  ↩
       0d 0h 42m 7s
```

## 13 Osmocom Control Interface

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

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

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

### 13.1 Control Interface Protocol

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

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

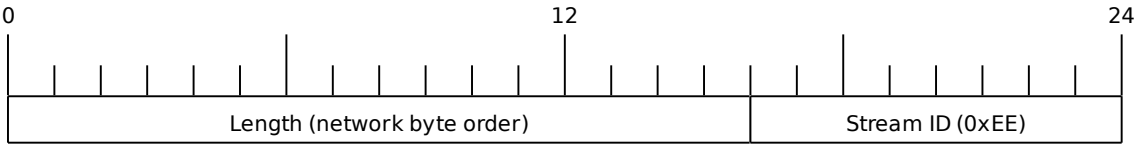



Figure 11: IPA header for control protocol

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

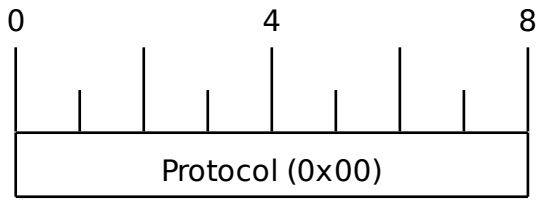



Figure 12: IPA extension header for control protocol

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

The fields specified below follow the following meaning:

**<id>**
A numeric identifier, uniquely identifying this particular operation. Value `0` is not allowed unless it's a TRAP message. It will be echoed back in any response to a particular request.

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

**<val>**
The value of the variable / field

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

#### 13.1.1 GET operation

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

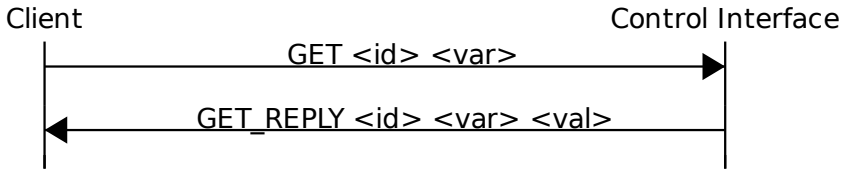



Figure 13: Control Interface GET operation (successful outcome)

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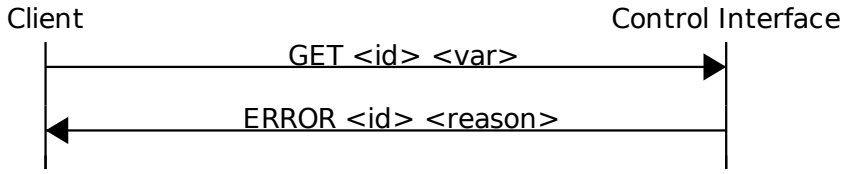



Figure 14: Control Interface GET operation (unsuccessful outcome)

#### 13.1.2 SET operation

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

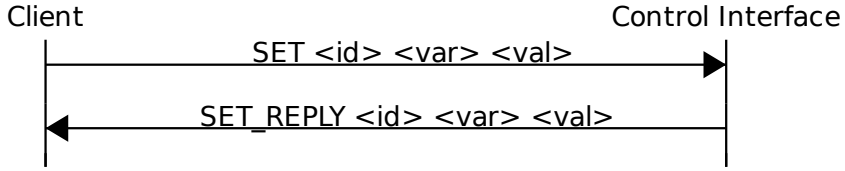



Figure 15: Control Interface SET operation (successful outcome)

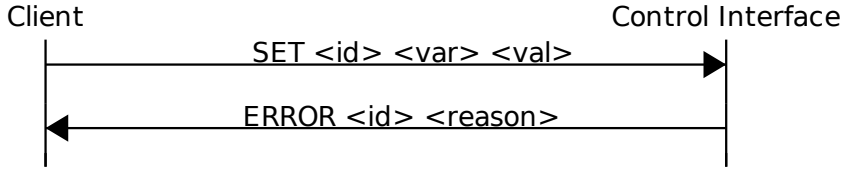



Figure 16: Control Interface SET operation (unsuccessful outcome)

#### 13.1.3 TRAP operation

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

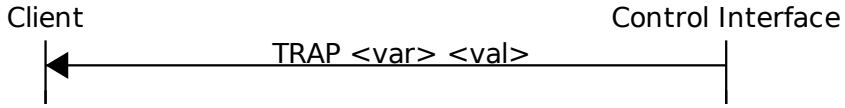



Figure 17: Control Interface TRAP operation

### 13.2 Common variables

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

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Table 5: Variables available over control interface

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

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

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

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

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

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

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

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

## 13.3 Control Interface python examples

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

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

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

Internally it uses "`rate_ctr.*`" variable described in Section 13.2 to get the list of counter groups and than request all the counters in each group. Applications interested in individual metrics can request it directly using `rate_ctr2csv.py` as an example.

### 13.3.1 Getting rate counters

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

```
$ ./scripts/osmo_rate_ctr2csv.py --header
Connecting to localhost:4249...
Getting rate counter groups info...
"group","counter","absolute","second","minute","hour","day"
"e1inp.0","hdlc:abort","0","0","0","0","0"
"e1inp.0","hdlc:bad_fcs","0","0","0","0","0"
"e1inp.0","hdlc:overrun","0","0","0","0","0"
"e1inp.0","alarm","0","0","0","0","0"
"e1inp.0","removed","0","0","0","0","0"
```

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```
"bsc.0","chreq:total","0","0","0","0","0"
"bsc.0","chreq:no_channel","0","0","0","0","0"
...
"msc.0","call:active","0","0","0","0","0"
"msc.0","call:complete","0","0","0","0","0"
"msc.0","call:incomplete","0","0","0","0","0"
Completed: 44 counters from 3 groups received.
```

#### 13.3.2 Setting a value

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

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

#### 13.3.3 Getting a value

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

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

#### 13.3.4 Listening for traps

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

**Example: Using osmo_ctrl.py to listen for traps:**

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

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

## 14 Osmocom Counters

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

### 14.1 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>

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## 14.2 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

## 14.3 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.

## 14.4 Statistic Levels

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

### 14.4.1 Global

These are global statistics.

### 14.4.2 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.

### 14.4.3 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.

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## 14.5 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.

### 14.5.1 Configuring a stats reporter

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

**Example 14.1** Log statistics

```
OsmoBSC> enable
OsmoBSC# configure terminal
OsmoBSC(config)# stats interval 60 ❶
OsmoBSC(config)# stats reporter log ❷
OsmoBSC(config-stats)# level global ❸
OsmoBSC(config-stats)# enable ❹
```

❶ The interval determines how often the statistics are reported.

❷ Write the statistic information to any configured log target.

❸ Report only `global` statistics (can be `global`, `peer`, or `subscriber`).

❹ 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

**Example 14.2** Report statistics to statsd

```
OsmoBSC> enable
OsmoBSC# configure terminal
OsmoBSC(config)# stats interval 10
OsmoBSC(config)# stats reporter statsd ❶
OsmoBSC(config-stats)# prefix BSC1 ❷
OsmoBSC(config-stats)# level subscriber ❸
OsmoBSC(config-stats)# remote-ip 1.2.3.4 ❹
OsmoBSC(config-stats)# remote-port 8125 ❺
OsmoBSC(config-stats)# enable
```

❶ Configure the statsd reporter.

❷ Prefix the reported statistics. This is useful to distinguish statistics from multiple instances of the same service.

❸ Report only `global` statistics or include `peer` or `subscriber` statistics as well.

❹ IP address of the statsd server.

❺ UDP port of the statsd server. Statsd by default listens to port 8125.

You can use Netdata (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 The list of available charts which includes all the rate counters reported via statsD is available through: http://localhost:19999/api/v1/charts

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## 14.6 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.

### 14.6.1 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 14.3** Report statistics to statsd

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

❶ Set the gathering interval (sec.)

❷ Set how many TCP sockets statistics to gather per interval.

### 14.6.2 Generated stats items

| Name | Description |
|---|---|
| tcp:unacked | unacknowledged packets. |
| tcp:lost | unacknowledged packets. |
| tcp:retrans | lost packets. |
| tcp:rtt | retransmitted packets. |
| tcp:rcv_rtt | roundtrip-time (receive). |
| tcp:notsent_bytes | bytes not yet sent. |
| tcp:rwnd_limited | time (usec) limited by receive window. |
| tcp:sndbuf_limited | Time (usec) limited by send buffer. |
| tcp:reord_seen | reordering events seen. |

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 14.4** VTY output of a stats item group of a TCP connection

```
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
```

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```
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
```

# 15 Counters

These counters and their description are based on OsmoGbProxy 0.1.0.21-5643 (OsmoGbProxy).

## 15.1 Rate Counters

Table 6: ns:nsvc - NSVC Peer Statistics

| Name | Reference | Description |
|---|---|---|
| packets:in | [?] | Packets at NS Level ( In) |
| packets:out | [?] | Packets at NS Level (Out) |
| packets:out:drop | [?] | Dropped Packets (Out) |
| bytes:in | [?] | Bytes at NS Level ( In) |
| bytes:out | [?] | Bytes at NS Level (Out) |
| bytes:out:drop | [?] | Dropped Bytes (Out) |
| blocked | [?] | NS-VC Block count |
| unblocked | [?] | NS-VC Unblock count |
| dead | [?] | NS-VC gone dead count |
| replaced | [?] | NS-VC replaced other count |
| nsei-chg | [?] | NS-VC changed NSEI count |
| inv-nsvci | [?] | NS-VCI was invalid count |
| inv-nsei | [?] | NSEI was invalid count |
| lost:alive | [?] | ALIVE ACK missing count |
| lost:reset | [?] | RESET ACK missing count |

Table 7: gbproxy:peer - GBProxy Peer Statistics

| Name | Reference | Description |
|---|---|---|
| blocked | [?] | BVC Block |
| unblocked | [?] | BVC Unblock |
| dropped | [?] | BVC blocked, dropped packet |
| inv-nsei | [?] | NSEI mismatch |
| tx-err | [?] | NS Transmission error |

Table 8: gbproxy:global - GBProxy Global Statistics

| Name | Reference | Description |
|---|---|---|
| inv-bvci | [?] | Invalid BVC Identifier |
| inv-lai | [?] | Invalid Location Area Identifier |
| inv-rai | [?] | Invalid Routing Area Identifier |
| inv-nsei | [?] | No BVC established for NSEI |

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Table 8: (continued)

| Name | Reference | Description |
|---|---|---|
| proto-err:bss | [?] | BSSGP protocol error (BSS ) |
| proto-err:sgsn | [?] | BSSGP protocol error (SGSN) |
| not-supp:bss | [?] | Feature not supported (BSS ) |
| not-supp:sgsn | [?] | Feature not supported (SGSN) |
| restart:sgsn | [?] | Restarted RESET procedure (SGSN) |
| tx-err:sgsn | [?] | NS Transmission error (SGSN) |
| error | [?] | Other error |
| mod-peer-err | [?] | Patch error: no peer |

### 15.2 Osmo Stat Items

NSVC Peer Statistics .ns.nsvc - NSVC Peer Statistics

| Name | Reference | Description | Unit |
|---|---|---|---|
| alive.delay | [?] | ALIVE response time | ms |

NS Bind Statistics .ns.bind - NS Bind Statistics

| Name | Reference | Description | Unit |
|---|---|---|---|
| tx_backlog_length | [?] | Transmit backlog length | packets |

## 16 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.

### 16.1 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 ❶
```

❶ Configure process to use *SCHED_RR* policy with real time priority 1

### 16.2 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.

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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:

```
cpu-sched
 cpu-affinity self 0x01 ❶
```

❶ Allow main thread (the one managing the VTY) only on CPU 0

Or otherwise:

```
cpu-sched
 cpu-affinity all 0x01 ❶
```

❶ 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 ❶
OsmoTRX> cpu-affinity TxLower 0x03 ❷
```

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

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

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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 and 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 ❶
```

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

# 17 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

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**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

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**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

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**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])

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**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]

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**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

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

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**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

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**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* [ietf-rfc3868])

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

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

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

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

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

**TOS**
Type Of Service; bit-field in IPv4 header, now re-used as DSCP (*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 (*IETF RFC 768* [ietf-rfc768])

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

**Um interface**
U mobile; Radio interface between MS and BTS

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

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

**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* [3gpp-ts-48-018]) 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.

Table 9: TCP/UDP port numbers

| L4 Protocol | Port Number | Purpose | Software |
|---|---|---|---|
| UDP | 1984 | Osmux | osmo-mgw, osmo-bts |
| UDP | 2427 | MGCP GW | osmo-bsc_mgcp, osmo-mgw |
| TCP | 2775 | SMPP (SMS interface for external programs) | osmo-nitb |
| TCP | 3002 | A-bis/IP OML | osmo-bts, osmo-bsc, osmo-nitb |
| TCP | 3003 | A-bis/IP RSL | osmo-bts, osmo-bsc, osmo-nitb |
| TCP | 4227 | telnet (VTY) | osmo-pcap-client |
| TCP | 4228 | telnet (VTY) | osmo-pcap-server |
| TCP | 4236 | Control Interface | osmo-trx |
| TCP | 4237 | telnet (VTY) | osmo-trx |
| TCP | 4238 | Control Interface | osmo-bts |

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Table 9: (continued)

| L4 Protocol | Port Number | Purpose | Software |
|---|---|---|---|
| TCP | 4239 | telnet (VTY) | osmo-stp |
| TCP | 4240 | telnet (VTY) | osmo-pcu |
| TCP | 4241 | telnet (VTY) | osmo-bts |
| TCP | 4242 | telnet (VTY) | osmo-nitb, osmo-bsc, cellmgr-ng |
| TCP | 4243 | telnet (VTY) | osmo-bsc_mgcp, osmo-mgw |
| TCP | 4244 | telnet (VTY) | osmo-bsc_nat |
| TCP | 4245 | telnet (VTY) | osmo-sgsn |
| TCP | 4246 | telnet (VTY) | osmo-gbproxy |
| TCP | 4247 | telnet (VTY) | OsmocomBB |
| TCP | 4249 | Control Interface | osmo-nitb, osmo-bsc |
| TCP | 4250 | Control Interface | osmo-bsc_nat |
| TCP | 4251 | Control Interface | osmo-sgsn |
| TCP | 4252 | telnet (VTY) | sysmobts-mgr |
| TCP | 4253 | telnet (VTY) | osmo-gtphub |
| TCP | 4254 | telnet (VTY) | osmo-msc |
| TCP | 4255 | Control Interface | osmo-msc |
| TCP | 4256 | telnet (VTY) | osmo-sip-connector |
| TCP | 4257 | Control Interface | osmo-ggsn, ggsn (OpenGGSN) |
| TCP | 4258 | telnet (VTY) | osmo-hlr |
| TCP | 4259 | Control Interface | osmo-hlr |
| TCP | 4260 | telnet (VTY) | osmo-ggsn |
| TCP | 4261 | telnet (VTY) | osmo-hnbgw |
| TCP | 4262 | Control Interface | osmo-hnbgw |
| TCP | 4263 | Control Interface | osmo-gbproxy |
| TCP | 4264 | telnet (VTY) | osmo-cbc |
| TCP | 4265 | Control Interface | osmo-cbc |
| TCP | 4266 | D-GSM MS Lookup: mDNS serve | osmo-hlr |
| TCP | 4267 | Control Interface | osmo-mgw |
| TCP | 4268 | telnet (VTY) | osmo-uecups |
| SCTP | 4268 | UECUPS | osmo-uecups |
| TCP | 4269 | telnet (VTY) | osmo-e1d |
| TCP | 4270 | telnet (VTY) | osmo-isdntap |
| TCP | 4271 | telnet (VTY) | osmo-smlc |
| TCP | 4272 | Control Interface | osmo-smlc |
| TCP | 4273 | telnet (VTY) | osmo-hnodeb |
| TCP | 4274 | Control Interface | osmo-hnodeb |
| TCP | 4275 | telnet (VTY) | osmo-upf |
| TCP | 4276 | Control Interface | osmo-upf |
| TCP | 4277 | telnet (VTY) | osmo-pfcp-tool |
| TCP | 4278 | Control Interface | osmo-pfcp-tool |
| UDP | 4729 | GSMTAP | Almost every osmocom project |
| TCP | 5000 | A/IP | osmo-bsc, osmo-bsc_nat |
| UDP | 23000 | GPRS-NS over IP default port | osmo-pcu, osmo-sgsn, osmo-gbproxy |
| TCP | 48049 | BSC-CBC (CBSP) default port | osmo-bsc, osmo-cbc |

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# B Bibliography / References

#### B.0.0.0.1 References


[1] [userman-ice1usb] Osmocom Project: icE1usb User Manual.

[2] [userman-ogt] Pau Espin: osmo-gsm-tester User Manual.

[3] [userman-remsim] Harald Welte: osmo-remsim User Manual.

[4] [osmobts-abis-spec] Neels Hofmeyr & Harald Welte. OsmoBTS Abis Protocol Specification. https://ftp.osmocom.org/docs/latest/osmobts-abis.pdf

[5] [userman-osmobsc] Osmocom Project: OsmoBSC User Manual. https://ftp.osmocom.org/docs/latest/osmobsc-usermanual.pdf

[6] [vty-ref-osmobsc] Osmocom Project: OsmoBSC VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmobsc-vty-reference.pdf

[7] [userman-osmobts] Osmocom Project: OsmoBTS User Manual. https://ftp.osmocom.org/docs/latest/osmobts-usermanual.pdf

[8] [vty-ref-osmobts] Osmocom Project: OsmoBTS VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmobts-trx-vty-reference.pdf https://ftp.osmocom.org/docs/latest/osmobts-sysmo-vty-reference.pdf https://ftp.osmocom.org/docs/latest/osmobts-lc15-vty-reference.pdf https://ftp.osmocom.org/docs/latest/-osmobts-oc2g-vty-reference.pdf https://ftp.osmocom.org/docs/latest/osmobts-octphy-vty-reference.pdf https://ftp.osmocom.org/docs/latest/osmobts-virtual-vty-reference.pdf

[9] [userman-osmocbc] Osmocom Project: OsmoCBC User Manual. https://ftp.osmocom.org/docs/latest/-osmocbc-usermanual.pdf

[10] [vty-ref-osmocbc] Osmocom Project: OsmoCBC VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmocbc-vty-reference.pdf

[11] [userman-osmogbproxy] Osmocom Project: OsmoGBProxy User Manual. https://ftp.osmocom.org/docs/-latest/osmogbproxy-usermanual.pdf

[12] [vty-ref-osmogbproxy] Osmocom Project: OsmoGBPRoxy VTY Reference Manual. https://ftp.osmocom.org/-docs/latest/osmogbproxy-vty-reference.pdf

[13] [userman-osmoggsn] Osmocom Project: OpenGGSN User Manual. https://ftp.osmocom.org/docs/latest/-osmoggsn-usermanual.pdf

[14] [vty-ref-osmoggsn] Osmocom Project: OsmoGGSN VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmoggsn-vty-reference.pdf

[15] [userman-osmohlr] Osmocom Project: OsmoHLR User Manual. https://ftp.osmocom.org/docs/latest/osmohlr-usermanual.pdf

[16] [vty-ref-osmohlr] Osmocom Project: OsmoHLR VTY Reference Manual. https://ftp.osmocom.org/docs/latest/-osmohlr-vty-reference.pdf

[17] [userman-osmohnbgw] Osmocom Project: OsmoHNBGW User Manual. https://ftp.osmocom.org/docs/latest/-osmohnbgw-usermanual.pdf

[18] [vty-ref-osmohnbgw] Osmocom Project: OsmoHNBGW VTY Reference Manual. https://ftp.osmocom.org/-docs/latest/osmohnbgw-vty-reference.pdf

[19] [userman-osmomgw] Osmocom Project: OsmoMGW User Manual. https://ftp.osmocom.org/docs/latest/-osmomgw-usermanual.pdf

[20] [vty-ref-osmomgw] Osmocom Project: OsmoMGW VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmomgw-vty-reference.pdf


Copyright © 2013-2021 sysmocom - s.f.m.c. GmbH 

[21] [userman-osmomsc] Osmocom Project: OsmoMSC User Manual. https://ftp.osmocom.org/docs/latest/-osmomsc-usermanual.pdf

[22] [vty-ref-osmomsc] Osmocom Project: OsmoMSC VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmomsc-vty-reference.pdf

[23] [userman-osmonitb] Osmocom Project: OsmoNITB User Manual. https://ftp.osmocom.org/docs/latest/-osmonitb-usermanual.pdf

[24] [vty-ref-osmonitb] Osmocom Project: OsmoNITB VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmonitb-vty-reference.pdf

[25] [userman-osmopcu] Osmocom Project: OsmoPCU User Manual. https://ftp.osmocom.org/docs/latest/-osmopcu-usermanual.pdf

[26] [vty-ref-osmopcu] Osmocom Project: OsmoPCU VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmopcu-vty-reference.pdf

[27] [userman-osmosgsn] Osmocom Project: OsmoSGSN User Manual. https://ftp.osmocom.org/docs/latest/-osmosgsn-usermanual.pdf

[28] [vty-ref-osmosgsn] Osmocom Project: OsmoSGSN VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmosgsn-vty-reference.pdf

[29] [userman-osmosipconnector] Osmocom Project: OsmoSIPconnector User Manual. https://ftp.osmocom.org/-docs/latest/osmosipconnector-usermanual.pdf

[30] [vty-ref-osmosipconnector] Osmocom Project: OsmoSIPconnector VTY Reference Manual. https://ftp.osmocom.org/docs/latest/osmosipconnector-vty-reference.pdf

[31] [userman-osmosmlc] Osmocom Project: OsmoSMLC User Manual. https://ftp.osmocom.org/docs/latest/-osmosmlc-usermanual.pdf

[32] [vty-ref-osmosmlc] Osmocom Project: OsmoSMLC VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmosmlc-vty-reference.pdf

[33] [userman-osmostp] Osmocom Project: OsmoSTP User Manual. https://ftp.osmocom.org/docs/latest/osmostp-usermanual.pdf

[34] [vty-ref-osmostp] Osmocom Project: OsmoSTP VTY Reference Manual. https://ftp.osmocom.org/docs/latest/-osmostp-vty-reference.pdf

[35] [userman-osmotrx] Osmocom Project: OsmoTRX User Manual. https://ftp.osmocom.org/docs/latest/osmotrx-usermanual.pdf

[36] [vty-ref-osmotrx] Osmocom Project: OsmoTRX VTY Reference Manual. https://ftp.osmocom.org/docs/-latest/osmotrx-uhd-vty-reference.pdf https://ftp.osmocom.org/docs/latest/osmotrx-lms-vty-reference.pdf https://ftp.osmocom.org/docs/latest/osmotrx-ipc-vty-reference.pdf https://ftp.osmocom.org/docs/latest/-osmotrx-usrp1-vty-reference.pdf

[37] [3gpp-ts-23-041] 3GPP TS 23.041: Technical realization of Cell Broadcast Service (CBS)

[38] [3gpp-ts-23-048] 3GPP TS 23.048: Security mechanisms for the (U)SIM application toolkit; Stage 2 https://www.3gpp.org/DynaReport/23048.htm

[39] [3gpp-ts-23-236] 3GPP TS 23.236: Intra-domain connection of Radio Access Network (RAN) nodes to multiple Core Network (CN) nodes https://www.3gpp.org/DynaReport/23236.htm

[40] [3gpp-ts-24-007] 3GPP TS 24.007: Mobile radio interface signalling layer 3; General Aspects https://www.3gpp.org/DynaReport/24007.htm

[41] [3gpp-ts-24-008] 3GPP TS 24.008: Mobile radio interface Layer 3 specification; Core network protocols; Stage 3. https://www.3gpp.org/dynareport/24008.htm

Copyright © 2013-2021 sysmocom - s.f.m.c. GmbH 

[42] [3gpp-ts-31-101] 3GPP TS 31.101: UICC-terminal interface; Physical and logical characteristics https://www.3gpp.org/DynaReport/31101.htm

[43] [3gpp-ts-31-102] 3GPP TS 31.102: Characteristics of the Universal Subscriber Identity Module (USIM) application https://www.3gpp.org/DynaReport/31102.htm

[44] [3gpp-ts-31-103] 3GPP TS 31.103: Characteristics of the IMS Subscriber Identity Module (ISIM) application https://www.3gpp.org/DynaReport/31103.htm

[45] [3gpp-ts-31-111] 3GPP TS 31.111: Universal Subscriber Identity Module (USIM) Application Toolkit (USAT) https://www.3gpp.org/DynaReport/31111.htm

[46] [3gpp-ts-31-115] 3GPP TS 31.115: Secured packet structure for (Universal) Subscriber Identity Module (U)SIM Toolkit applications https://www.3gpp.org/DynaReport/31115.htm

[47] [3gpp-ts-31-116] 3GPP TS 31.116: Remote APDU Structure for (U)SIM Toolkit applications https://www.3gpp.org/DynaReport/31116.htm

[48] [3gpp-ts-35-205] 3GPP TS 35.205: 3G Security; Specification of the MILENAGE algorithm set: General

[49] [3gpp-ts-35-206] 3GPP TS 35.206: 3G Security; Specification of the MILENAGE algorithm set: Algorithm specification https://www.3gpp.org/DynaReport/35206.htm

[50] [3gpp-ts-44-006] 3GPP TS 44.006: Mobile Station - Base Station System (MS - BSS) interface; Data Link (DL) layer specification https://www.3gpp.org/DynaReport/44006.htm

[51] [3gpp-ts-44-018] 3GPP TS 44.018: Mobile radio interface layer 3 specification; Radio Resource Control (RRC) protocol https://www.3gpp.org/DynaReport/44018.htm

[52] [3gpp-ts-44-064] 3GPP TS 44.064: Mobile Station - Serving GPRS Support Node (MS-SGSN); Logical Link Control (LLC) Layer Specification https://www.3gpp.org/DynaReport/44064.htm

[53] [3gpp-ts-45-002] 3GPP TS 45.002: Digital cellular telecommunications system (Phase 2+) (GSM); GSM/EDGE Multiplexing and multiple access on the radio path https://www.3gpp.org/DynaReport/45002.htm

[54] [3gpp-ts-48-008] 3GPP TS 48.008: Mobile Switching Centre - Base Station system (MSC-BSS) interface; Layer 3 specification https://www.3gpp.org/DynaReport/48008.htm

[55] [3gpp-ts-48-016] 3GPP TS 48.016: General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN) interface; Network service https://www.3gpp.org/DynaReport/48016.htm

[56] [3gpp-ts-48-018] 3GPP TS 48.018: General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN); BSS GPRS protocol (BSSGP) https://www.3gpp.org/DynaReport/48018.htm

[57] [3gpp-ts-48-049] 3GPP TS 48.049: Digital cellular communications system; Base Station Controller - Cell Broadcast Centre (BSC-CBC) interface specification; Cell Broadcast Service Protocol (CBSP) https://www.3gpp.org/DynaReport/48049.htm

[58] [3gpp-ts-48-056] 3GPP TS 48.056: Base Station Controller - Base Transceiver Station (BSC - BTS) interface; Layer 2 specification https://www.3gpp.org/DynaReport/48056.htm

[59] [3gpp-ts-48-058] 3GPP TS 48.058: Base Station Controller - Base Transceiver Station (BSC - BTS) Interface; Layer 3 specification https://www.3gpp.org/DynaReport/48058.htm

[60] [3gpp-ts-51-011] 3GPP TS 51.011: Specification of the Subscriber Identity Module - Mobile Equipment (SIM-ME) interface

[61] [3gpp-ts-51-014] 3GPP TS 51.014: Specification of the SIM Application Toolkit for the Subscriber Identity Module - Mobile Equipment (SIM - ME) interface https://www.3gpp.org/DynaReport/51014.htm

[62] [3gpp-ts-52-021] 3GPP TS 52.021: Network Management (NM) procedures and messages on the A-bis interface https://www.3gpp.org/DynaReport/52021.htm

[63] [etsi-tr102216] ETSI TR 102 216: Smart cards https://www.etsi.org/deliver/etsi_tr/102200_102299/102216/-03.00.00_60/tr_102216v030000p.pdf

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[64] [etsi-ts102221] ETSI TS 102 221: Smart Cards; UICC-Terminal interface; Physical and logical characteristics https://www.etsi.org/deliver/etsi_ts/102200_102299/102221/13.01.00_60/ts_102221v130100p.pdf

[65] [etsi-ts101220] ETSI TS 101 220: Smart Cards; ETSI numbering system for telecommunication application providers https://www.etsi.org/deliver/etsi_ts/101200_101299/101220/12.00.00_60/ts_101220v120000p.pdf

[66] [etsi-ts102671] ETSI TS 102 671: Smart Cards; Machine to Machine UICC; Physical and logical characteristics https://www.etsi.org/deliver/etsi_ts/102600_102699/102671/18.01.00_60/ts_102671v180100p.pdf

[67] [ieee-802.1q] IEEE 802.1Q: Bridges and Bridged Networks https://ieeexplore.ieee.org/document/6991462

[68] [ietf-rfc768] IETF RFC 768: User Datagram Protocol https://tools.ietf.org/html/rfc768

[69] [ietf-rfc791] IETF RFC 791: Internet Protocol https://tools.ietf.org/html/rfc791

[70] [ietf-rfc793] IETF RFC 793: Transmission Control Protocol https://tools.ietf.org/html/rfc793

[71] [ietf-rfc1035] IETF RFC 1035: Domain Names - Implementation and Specification https://tools.ietf.org/html/-rfc1035

[72] [ietf-rfc1350] IETF RFC 1350: Trivial File Transfer Protocol https://tools.ietf.org/html/rfc1350

[73] [ietf-rfc2131] IETF RFC 2131: Dynamic Host Configuration Protocol https://tools.ietf.org/html/rfc2131

[74] [ietf-rfc2474] IETF RFC 2474: Definition of the Differentiated Services Field (DS Field) in the IPv44 and IPv6 Headers https://tools.ietf.org/html/rfc2474

[75] [ietf-rfc2719] IETF RFC 2719: Signal Transport over IP https://tools.ietf.org/html/rfc2719

[76] [ietf-rfc3331] IETF RFC 3331: Message Transfer Part 2 User Adaptation Layer https://tools.ietf.org/html/-rfc3331

[77] [ietf-rfc3550] IETF RFC 3550: RTP: A Transport protocol for Real-Time Applications https://tools.ietf.org/-html/rfc3550

[78] [ietf-rfc3596] IETF RFC 3596: DNS Extensions to Support IP Version 6 https://tools.ietf.org/html/rfc3596

[79] [ietf-rfc3868] IETF RFC 3868: SCCP User Adaptation Layer https://tools.ietf.org/html/rfc3868

[80] [ietf-rfc4165] IETF RFC 4165: Message Transfer Part 2 Peer-to-Peer Adaptation Layer https://tools.ietf.org/-html/rfc4165

[81] [ietf-rfc4251] IETF RFC 4251: The Secure Shell (SSH) Protocol Architecture https://tools.ietf.org/html/-rfc4251

[82] [ietf-rfc4666] IETF RFC 4666: Message Transfer Part 3 User Adaptation Layer https://tools.ietf.org/html/-rfc4666

[83] [ietf-rfc5771] IETF RFC 5771: IANA Guidelines for IPv4 Multicast Address Assignments https://tools.ietf.org/html/rfc5771

[84] [itu-t-q701] ITU-T Q.701: Functional Description of the Message Transfer Part (MTP) https://www.itu.int/rec/-T-REC-Q.701/en/

[85] [itu-t-q711] ITU-T Q.711: Functional Description of the Signalling Connection Control Part https://www.itu.int/rec/T-REC-Q.711/en/

[86] [itu-t-q713] ITU-T Q.713: Signalling connection control part formats and codes https://www.itu.int/rec/T-REC-Q.713/en/

[87] [itu-t-q714] ITU-T Q.714: Signalling connection control part procedures https://www.itu.int/rec/T-REC-Q.714/en/

[88] [itu-t-q921] ITU-T Q.921: ISDN user-network interface - Data link layer specification https://www.itu.int/rec/-T-REC-Q.921/en

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[89] [smpp-34] SMPP Develoepers Forum. Short Message Peer-to-Peer Protocol Specification v3.4 https://docs.nimta.com/SMPP_v3_4_Issue1_2.pdf

[90] [gnu-agplv3] Free Software Foundation. GNU Affero General Public License. https://www.gnu.org/licenses/-agpl-3.0.en.html

[91] [freeswitch_pbx] FreeSWITCH SIP PBX https://freeswitch.org

[92] [tw-ts-001] TW-TS-001: Enhanced RTP transport of FR and EFR codec frames in an IP-based GSM RAN https://www.freecalypso.org/specs/tw-ts-001-v010100.txt

[93] [tw-ts-002] TW-TS-002: Enhanced RTP transport of HRv1 codec frames in an IP-based GSM RAN https://www.freecalypso.org/specs/tw-ts-002-v010100.txt

[94] [tw-ts-003] TW-TS-003: BSSMAP extension for selection of enhanced RTP transport formats https://www.freecalypso.org/specs/tw-ts-003-v010002.txt

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