sysmocom

sysmocom - s.f.m.c. GmbH

OsmoPCU User Manual

by Harald Welte

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

### 1 Foreword
1.1 Acknowledgements ........................................... 1  
1.2 Endorsements ............................................. 2  

### 2 Preface
2.1 FOSS lives by contribution! ................................. 2  
2.2 Osmocom and sysmocom ....................................... 2  
2.3 Corrections .................................................. 3  
2.4 Legal disclaimers ............................................. 3  
    2.4.1 Spectrum License ...................................... 3  
    2.4.2 Software License ...................................... 3  
    2.4.3 Trademarks ............................................ 3  
    2.4.4 Liability ............................................. 3  
    2.4.5 Documentation License ................................. 4  

### 3 Introduction
3.1 Required Skills ............................................. 4  
3.2 Getting assistance ........................................... 4  

### 4 Overview
4.1 About OsmoPCU ............................................ 5  
4.2 Software Components ....................................... 5  
    4.2.1 Gb Implementation .................................. 5  
    4.2.2 pcu_sock Interface to OsmoBTS ...................... 5  

### 5 Running OsmoPCU
5.1 SYNOPSIS .................................................. 6  
5.2 OPTIONS .................................................. 6  

### 6 The Osmocom VTY Interface
6.1 Accessing the telnet VTY .................................... 7  
6.2 VTY Nodes .................................................. 8  
6.3 Interactive help ............................................ 8  
    6.3.1 The question-mark (?) command ..................... 8  
    6.3.2 TAB completion ...................................... 9  
    6.3.3 The list command ................................... 10  
    6.3.4 The attribute system ................................. 12  
    6.3.5 The expert mode .................................... 13  

Copyright © 2013-2021 sysmocom - s.f.m.c. GmbH
7  OsmoPCU Logging System
   7.1  Log categories ................................................................. 14
   7.2  Log levels ................................................................. 14
   7.3  Log printing options ...................................................... 15
   7.4  Log filters ................................................................. 15
   7.5  Log targets ...................................................................... 15
      7.5.1  Logging to the VTY ....................................................... 15
      7.5.2  Logging to the ring buffer ........................................... 16
      7.5.3  Logging via gsmtap .................................................... 16
      7.5.4  Logging to a file ....................................................... 17
      7.5.5  Logging to syslog ...................................................... 18
      7.5.6  Logging to systemd-journal ....................................... 18
      7.5.7  Logging to stderr ..................................................... 19
8  Configuring OsmoPCU ............................................................. 20
   8.1  Configuring the Coding Schemes and Rate Adaption ................. 20
      8.1.1  Initial Coding Scheme ................................................ 20
      8.1.2  Maximum Coding Scheme .......................................... 20
      8.1.3  Rate Adaption Error Thresholds .................................... 20
      8.1.4  Rate Adaption Link Quality Thresholds .......................... 21
      8.1.5  Data Size based CS downgrade Threshold ....................... 21
   8.2  Miscellaneous Configuration / Tuning Parameters ..................... 21
      8.2.1  Downlink TBF idle time ............................................. 21
      8.2.2  MS idle time .......................................................... 21
      8.2.3  Forcing two-phase access .......................................... 21
   8.3  Configuring BSSGP flow control ......................................... 21
      8.3.1  Normal BSSGP Flow Control Tuning parameters ................ 21
      8.3.2  Extended BSSGP Flow Control Tuning parameters ............ 22
   8.4  Configuring LLC queue .................................................... 22
   8.5  Configuring MS power control .......................................... 22
   8.6  Configuring Network Assisted Cell Change (NACC) ................... 23
      8.6.1  Neighbor Address Resolution ...................................... 23
      8.6.2  System Information Resolution .................................... 23
   8.7  GPRS vs EGPRS considerations .......................................... 24
      8.7.1  Configuration ......................................................... 24
      8.7.2  GPRS+EGPRS multiplexing .......................................... 25
9  Counters ............................................................................. 25
# OsmoPCU User Manual

## 10 Gb interface using libosmogb

10.1 Gb interface configuration .............................................. 28
  10.1.1 NS-over-UDP configuration ........................................ 28
  10.1.2 NS-over-FR-GRE configuration .................................... 29
  10.1.3 NS Timer configuration ............................................. 29
10.2 Examining Gb interface status ........................................ 29
10.3 FIXME ................................................................. 30
  10.3.1 Blocking / Unblocking / Resetting NS Virtual Connections .... 30
10.4 Gb interface logging filters .......................................... 30

## 11 QoS, DSCP/TOS, Priority and IEEE 802.1q PCP

11.1 IP Level (DSCP) ....................................................... 31
11.2 Packet Priority ........................................................ 31
11.3 Ethernet Level (PCP) .................................................. 32
11.4 Putting things together ............................................... 33
  11.4.1 Full example of QoS for osmo-pcu uplink QoS .................. 33

## 12 VTY Process and Thread management

12.1 Scheduling Policy ..................................................... 34
12.2 CPU-Affinity Mask .................................................... 34

## 13 Glossary

A Osmocom TCP/UDP Port Numbers ...................................... 44

B Bibliography / References ............................................. 45
  B.0.0.1 References ...................................................... 45

C GNU Free Documentation License ................................... 49
  C.1 PREAMBLE .......................................................... 49
  C.2 APPLICABILITY AND DEFINITIONS ................................ 49
  C.3 VERBATIM COPYING ................................................. 50
  C.4 COPYING IN QUANTITY ............................................... 50
  C.5 MODIFICATIONS ..................................................... 51
  C.6 COMBINING DOCUMENTS .............................................. 52
  C.7 COLLECTIONS OF DOCUMENTS ..................................... 52
  C.8 AGGREGATION WITH INDEPENDENT WORKS ...................... 52
  C.9 TRANSLATION ........................................................ 53
  C.10 TERMINATION ........................................................ 53
  C.11 FUTURE REVISIONS OF THIS LICENSE ......................... 53
  C.12 RELICENSING ....................................................... 53
  C.13 ADDENDUM: How to use this License for your documents .... 54
# Foreword

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

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

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

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

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

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

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

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

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

## Acknowledgements

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

- Dieter Spaar for being the most amazing reverse engineer I’ve met in my career
- Holger Freyther for his many code contributions and for shouldering a lot of the maintenance work, setting up Jenkins - and being crazy enough to co-start sysmocom as a company with me :) 
- Andreas Eversberg for taking care of Layer2 and Layer3 of OsmocomBB, and for his work on OsmoBTS and OsmoPCU
- Sylvain Munaut for always tackling the hardest problems, particularly when it comes closer to the physical layer
- Chaos Computer Club for providing us a chance to run real-world deployments with tens of thousands of subscribers every year
- Bernd Schneider of Netzing AG for funding early ip.access nanoBTS support
- On-Waves ehf for being one of the early adopters of OpenBSC and funding a never ending list of features, fixes and general improvement of pretty much all of our GSM network element implementations
- sysmocom, for hosting and funding a lot of Osmocom development, the annual Osmocom Developer Conference and releasing this manual.
• Jan Luebbe, Stefan Schmidt, Daniel Willmann, Pablo Neira, Nico Golde, Kevin Redon, Ingo Albrecht, Alexander Huemer, Alexander Chemeris, Max Suraev, Tobias Engel, Jacob Erlbeck, Ivan Kluchnikov

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

1.2 Endorsements

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

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

2 Preface

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

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

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

2.1 FOSS lives by contribution!

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

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

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

We’re looking forward to receiving your contributions.

2.2 Osmocom and sysmocom

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

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

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

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

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

2.4 Legal disclaimers

2.4.1 Spectrum License

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

⚠️ Warning

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

2.4.2 Software License

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

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

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

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

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

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

4.1 About OsmoPCU

OsmoPCU is the Osmocom implementation of the GPRS PCU (Packet Control Unit) element inside the GPRS network. The OsmoPCU is co-located within the BTS and connects to OsmoBTS via its PCU socket interface. On the other side, OsmoPCU is connected via the Gb interface to the SGSN.

![GPRS network architecture with PCU in BTS](image)

Figure 1: GPRS network architecture with PCU in BTS

4.2 Software Components

OsmoPCU consists of a variety of components, including

- Gb interface (NS/BSSGP protocol)
- `pcu_sock` interface towards OsmoBTS
- TBF management for uplink and downlink TBF
- RLC/MAC protocol implementation
- per-MS context for each MS currently served
- CSN.1 encoding/decoding routines

4.2.1 Gb Implementation

OsmoPCU implements the ETSI/3GPP specified Gb interface, including TS 08.16 (NS), TS 08.18 (BSSGP) protocols. As transport layer for NS, it supports NS/IP (NS encapsulated in UDP/IP).

The actual Gb Implementation is part of the libosmogb library, which is in turn part of the libosmocore software package. This allows the same Gb implementation to be used from OsmoPCU, OsmoGbProxy as well as OsmoSGSN.

4.2.2 `pcu_sock` Interface to OsmoBTS

The interface towards OsmoBTS is called `pcu_sock` and implemented as a set of non-standardized primitives over a unix domain socket. The default file system path for this socket is `/tmp/pcu_bts`.

The PCU socket can be changed on both OsmoBTS and OsmoPCU to a different file/path name, primarily to permit running multiple independent BTS+PCU pairs on a single Linux machine without having to use filesystem namespaces or other complex configurations.

**Note**

If you change the PCU socket path on OsmoBTS by means of the `pcu-socket` VTY configuration command, you must ensure to make the identical change on the OsmoPCU side.
5 Running OsmoPCU

The OsmoPCU executable (osmo-pcu) offers the following command-line options:

5.1 SYNOPSIS

```
```

5.2 OPTIONS

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

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

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

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

- **-r, --realtime PRIOR**
  Enable use of the Linux kernel realtime priority scheduler with the specified priority. It is recommended you use this option on low-performance embedded systems or systems that encounter high non-GSM/GPRS load.

- **-m, --mcc MCC**
  Use the given MCC instead of that provided by BTS via PCU socket

- **-n, --mnc MNC**
  Use the given MNC instead of that provided by BTS via PCU socket

- **-i, --gsmtap-ip A.B.C.D**
  Send Um interface trace via GSMTAP to specified IP address

6 The Osmocom VTY Interface

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

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

The interactive telnet VTY is used to

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

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

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

## 6.1 Accessing the telnet VTY

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

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

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

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

The VTY by default has the following minimal nodes:

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

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

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

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

6.3 Interactive help

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

---

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

---

6.3.1 The question-mark (?) command

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

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

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

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

**Example: Typing \texttt{?} after a partial command**

```
OsmoMSC> show
version Displays program version
online-help Online help
history Display the session command history
cs7 ITU-T Signaling System
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
```

Type \texttt{?} after the \texttt{show} command, the \texttt{?} itself will not be printed.

You may pick the \texttt{bsc} object and type \texttt{?} again:

**Example: Typing \texttt{?} after show bsc**

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

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

### 6.3.2 TAB completion

The VTY supports tab (tabulator) completion. Simply type any partial command and press \texttt{<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 \texttt{<tab>} pressed after typing only s as command**

```
OsmoMSC> s
show sms subscriber
```

Type \texttt{<tab>} here.

At this point, you may choose \texttt{show}, and then press \texttt{<tab>} again:

**Example: Use of \texttt{<tab>} pressed after typing show command**
6.3.3 The list command

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

Example: Typing list at start of OsmoMSC VIEW node prompt

```
OsmoMSC> list
```

```
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> scgp addressbook
show cs7 instance <0-15> scgp users
show cs7 instance <0-15> scgp ssn <0-65535>
show cs7 instance <0-15> scgp connections
show cs7 instance <0-15> scgp 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]
logging set-log-mask MASK
logging level (rll|cc|mm|rr|mncc|pag|msg|mgcp|ho|db|ref|ctrl|smpp|ranap|v1r|iucs|bssap|← sgs|lglobal|lapp|lmsg|lmux|lml|lmib|lsms|lctrl|lgtp|lstats|lgsup|loap|lss7|lsccp|lsua ← |lm3ua|lgmcp|ljlibuf|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) ← tmsi|id) SENDER_ID send .LINE
subscriber (msisdn|extension|imsi|tmsi|id) ID silent-call start (any|tch/f|tch/any|sdch)
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)
silent-call start
subscriber (msisdn|extension|imsi|tmsi|id) ID ms-test open-loop
subscriber (msisdn|extension|imsi|tmsi|id) ID paging
show statistics
show sms-queue
logging filter imsi IMSI
show smpp esme

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

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

OsmoMSC(config-net)# list
help
list
write terminal
write file
write memory
write
show running-config
exit
end
network country code <1-999>
mobile network code <0-999>
short name NAME
long name NAME
encryption a5 <0-3> [<0-3> [<0-3> [<0-3>]]]
authentication (optional|required)
rnlp 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
6.3.4 The attribute system

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

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

**Example: Typing show vty-attributes at the VTY prompt**

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

The attributes are symbolized through a single ASCII letter (flag) and do exist in three levels. This is more or less due to the technical aspects of the VTY implementation. For the user, the level of an attribute has only informative purpose.

The global attributes, which can be found under the same attribute letter in every osmocom application, exist on the top level. The Library specific attributes below are used in various osmocom libraries. Like with the global attributes the attribute flag letter stays the same throughout every osmocom application here as well. On the third level one can find the application specific attributes. Those are unique to each osmocom application and the attribute letters may have different meanings in different osmocom applications. To make the user more aware of this, lowercase letters were used as attribute flags.

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

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

```
OsmoBSC(config-net-bts)# list with-flags
  .... help
  .... list [with-flags]
  .... show vty-attributes
  .... show vty-attributes (application|library|global)
  .... write terminal
  .... write file [PATH]
  .... write memory
  .... write
  .... show running-config
  .... exit
  .... end
  .... type (unknown|bs11|nanobts|rbs2000|nokia_site|sysmobts)
  .... description .TEXT
  .... no description
  .... band BAND
  .... cell_identity <0-65535>
  .... dtx uplink [force]
  .... dtx downlink
  .... no dtx uplink
  .... no dtx downlink
  .... location_area_code <0-65535>
  .... base_station_id_code <0-63>
```
This command has no attributes assigned.

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

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

This command applies immediately.

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

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

### 6.3.5 The expert mode

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

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

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

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

<table>
<thead>
<tr>
<th>Command</th>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>^ bts &lt;0-255&gt; (activate-all-lchan</td>
<td>deactivate-all-lchan)</td>
<td>3</td>
</tr>
<tr>
<td>^ bts &lt;0-255&gt; trx &lt;0-255&gt; timeslot &lt;0-7&gt; sub-slot &lt;0-7&gt; mdcx A.B.C.D &lt;0-65535&gt;</td>
<td>4</td>
<td>This is a regular command that is always shown regardless of the mode.</td>
</tr>
<tr>
<td>^ bts &lt;0-255&gt; trx &lt;0-255&gt; timeslot &lt;0-7&gt; sub-slot &lt;0-7&gt; (borken</td>
<td>unused)</td>
<td>5</td>
</tr>
<tr>
<td>^ bts &lt;0-255&gt; trx &lt;0-255&gt; timeslot &lt;0-7&gt; sub-slot &lt;0-7&gt; handover &lt;0-255&gt;</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>^ bts &lt;0-255&gt; trx &lt;0-255&gt; timeslot &lt;0-7&gt; sub-slot &lt;0-7&gt; assignment</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>^ bts &lt;0-255&gt; smscb-command (normal</td>
<td>schedule</td>
<td>default) &lt;1-4&gt; HEXSTRING</td>
</tr>
</tbody>
</table>
7 libosmocore Logging System

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

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

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

The logging system is composed of

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

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

7.1 Log categories

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

7.2 Log levels

For each of the log categories (see Section 7.1), you can set an independent log level, controlling the level of verbosity. Log levels include:

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

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

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

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

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

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

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

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

Afterwards you can adjust specific categories as usual.

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

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

**log color**

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

**log timestamp**

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

**log print extended-timestamp**

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

**log print category**

Prefix each log message with the category name.

**log print category-hex**

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

**log print level**

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

**log print file**

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

7.4 Log filters

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

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

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

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

7.5 Log targets

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

7.5.1 Logging to the VTY

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

Logging to the VTY is disabled by default, and needs to be enabled explicitly for each such session. This means that multiple concurrent VTY sessions each have their own logging configuration. Once you close a VTY session, the log target will be destroyed and your log settings be lost. If you re-connect to the VTY, you have to again activate and configure logging, if you wish.
To create a logging target bound to a VTY, you have to use the following command: `logging enable` This doesn’t really activate the generation of any output messages yet, it merely creates and attaches a log target to the VTY session. The newly-created target still doesn’t have any filter installed, i.e. all log messages will be suppressed by default.

Next, you can configure the log levels for desired categories in your VTY session. See Section 7.1 for more details on categories and Section 7.2 for the log level details.

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

Finally, after having configured the levels, you still need to set the filter as it’s described in Section 7.4.

---

**Tip**

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

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

### 7.5.2 Logging to the ring buffer

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

It’s configured as follows:

```
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.

### 7.5.3 Logging via gsmtap

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

It’s configured as follows:

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

The hostname/ip argument is optional: if omitted the default 127.0.0.1 will be used. The log strings inside GSMTAP are already supported by Wireshark. Capturing for port 4729 on appropriate interface will reveal log messages including source file name and line number as well as application. This makes it easy to consolidate logs from several different network components alongside the air frames. You can also use Wireshark to quickly filter logs for a given subsystem, severity, file name etc.
Figure 2: Wireshark with logs delivered over GSMTAP

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

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

7.5.4 Logging to a file

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

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

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

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

**Tip**

Don't forget to use the `copy running-config startup-config` (or its short-hand `write file`) command to make your logging configuration persistent across application re-start.
Note
libosmocore provides file close-and-reopen support by SIGHUP, as used by popular log file rotating solutions such as https://github.com/logrotate/logrotate found in most GNU/Linux distributions.

7.5.5 Logging to syslog

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

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

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

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

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

7.5.6 Logging to systemd-journal

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

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


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

```
$ ./configure --enable-systemd-logging
```

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

You can configure systemd based logging in two ways:

Example: systemd-journal target with offloaded rendering

```
log systemd-journal raw
logging filter all 1
logging level set-all notice
```
raw logging handler, rendering offloaded to systemd.

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

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

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

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

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

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

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

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

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

### 7.5.7 Logging to stderr

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

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

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

### 8 Configuring OsmoPCU

Contrary to other network elements (like OsmoBSC, OsmoNITB), the OsmoPCU has a relatively simple minimum configuration. This is primarily because most of the PCU configuration happens indirectly from the BSC, who passes the configuration over A-bis OML via OsmoBTS and its PCU socket into OsmoPCU.

A minimal OsmoPCU configuration file is provided below for your reference:

**Example: Minimal OsmoPCU configuration file (osmo-pcu.cfg)**
pcu
  flow-control-interval 10 ①
  cs 2 ②
  alloc-algorithm dynamic ③
  gamma 0

① send a BSSGP flow-control PDU every 10 seconds
② start a TBF with the initial coding scheme 2
③ dynamically chose between single-slot or multi-slot TBF allocations depending on system load

However, there are plenty of tuning parameters for people interested to optimize PCU throughput or latency according to their requirements.

8.1 Configuring the Coding Schemes and Rate Adaption

As a reminder:

- GPRS supports Coding Schemes 1-4 (CS1-4), all of them use GMSK modulation (same as GSM).
- EGPRS supports MCS1-9, where MCS1-4 is GMSK, and MCS5-9 use 8-PSK modulation.

The range of Coding Schemes above only apply to RLCMAC data blocks; RLCMAC control blocks are always transmitted with CS1 (GMSK). Hence, CS1 is always supported and must be always permitted.

The BSC includes a bit-mask of permitted [E]GPRS coding schemes as part of the A-bis OML configuration, controlled by VTY gprs mode (none|gprs|egprs). This is passed from the BTS via the PCU socket into OsmoPCU, and the resulting set can be further constrained by OsmoPCU VTY configuration.

Some additional OsmoPCU parameters can be set as described below.

8.1.1 Initial Coding Scheme

You can use the `cs <1-4> [<1-4>]` command at the `pcu` VTY config node to set the initial GPRS coding scheme to be used. The optional second value allows to specify a different initial coding scheme for uplink.

Similarly, `mcs <1-9> [<1-9>]` can be used to set up the initial EGPRS coding scheme.

8.1.2 Maximum Coding Scheme

You can use the `cs max <1-4> [<1-4>]` command at the `pcu` VTY config node to set the maximum GPRS coding scheme that should be used as part of the rate adaption. The optional second value allows to specify a different maximum coding scheme for uplink.

Similarly, `mcs max <1-9> [<1-9>]` can be used to set up the maximum EGPRS coding scheme.

The actual Maximum Coding Scheme for each direction used at runtime is actually the result of taking the maximum value from the permitted GPRS coding schemes received by the BSC (or BTS) over PCUIF which is equal or lower tho the configured value.

Example: PCUIF announces permitted MCS bit-mask (MCS1 MCS2 MCS3 MCS4) and OsmoPCU is configured `mcs max 6`, then the actual maximum MCS used at runtime will be MCS4.

8.1.3 Rate Adaption Error Thresholds

You can use the `cs threshold <0-100> <0-100>` command at the `pcu` VTY config node to determine the upper and lower limit for the error rate percentage to use in the rate adaption. If the upper threshold is reached, a lower coding sheme is chosen, and if the lower threshold is reached, a higher coding scheme is chosen.
8.1.4 Rate Adaption Link Quality Thresholds

You can use the \texttt{cs link-quality-ranges \texttt{cs1 <0-35> cs2 <0-35> <0-35> cs3 <0-35> <0-35> cs4 <0-35>\}} command at the \texttt{pcu} VTY config node to tune the link quality ranges for the respective coding schemes.

8.1.5 Data Size based CS downgrade Threshold

You can use the \texttt{cs downgrade-threshold <1-10000>} command at the \texttt{pcu} VTY config node to ask the PCU to down-grade the coding scheme if less than the specified number of octets are left to be transmitted.

8.2 Miscellaneous Configuration / Tuning Parameters

8.2.1 Downlink TBF idle time

After a down-link TBF is idle (all data in the current LLC downlink queue for the MS has been transmitted), we can keep the TBF established for a configurable time. This avoids having to go through a new one or two phase TBF establishment once the next data for downlink arrives.

You can use the \texttt{dl-tbf-idle-time <1-5000>} to specify that time in units of milli-seconds. The default is 2 seconds.

8.2.2 MS idle time

Using the \texttt{ms-idle-time <1-7200>} command at the \texttt{pcu} VTY config node you can configure the number of seconds for which the PCU should keep the MS data structure alive before releasing it if there are no active TBF for this MS.

The OsmoPCU default value is 60 seconds, which is slightly more than what 3GPP TS 24.008 recommends for T3314 (44s).

The MS data structure only consumes memory in the PCU and does not require any resources of the air interface.

8.2.3 Forcing two-phase access

If the MS is using a single-phase access, you can still force it to use a two-phase access using the \texttt{two-phase-access} VTY configuration command at the \texttt{pcu} VTY config node.

8.3 Configuring BSSGP flow control

BSSGP between SGSN and PCU contains a two-level nested flow control mechanism:

1. one global flow control instance for the overall (downlink) traffic from the SGSN to this PCU
2. a per-MS flow control instance for each individual MS served by this PCU

Each of the flow control instance is implemented as a TBF (token bucket filter).

8.3.1 Normal BSSGP Flow Control Tuning parameters

You can use the following commands at the \texttt{pcu} VTY config node to tune the BSSGP flow control parameters:

\texttt{flow-control-interval <1-10>}

configure the interval (in seconds) between subsequent flow control PDUs from PCU to SGSN

\texttt{flow-control bucket-time <1-65534>}

set the target downlink maximum queueing time in centi-seconds. The PCU will attempt to adjust the advertised bucket size to match this target.
8.3.2 Extended BSSGP Flow Control Tuning parameters

There are some extended flow control related parameters at the pcu VTY config node that override the automatic flow control as specified in the BSSGP specification. Use them with care!

- **flow-control force-bvc-bucket-size <1-6553500>**
  - Force the BVC (global) bucket size to the given number of octets.

- **flow-control force-bvc-leak-rate <1-6553500>**
  - Force the BVC (global) bucket leak rate to the given number of bits/s.

- **flow-control force-ms-bucket-size <1-6553500>**
  - Force the per-MS bucket size to the given number of octets.

- **flow-control force-ms-leak-rate <1-6553500>**
  - Force the per-MS bucket leak rate to the given number of bits/s.

8.4 Configuring LLC queue

The downlink LLC queue in the PCU towards the MS can be tuned with a variety of parameters at the pcu VTY config node, depending on your needs.

- **queue lifetime <1-65534>**
  - Each downlink LLC PDU is assigned a lifetime by the SGSN, which is respected by the PDU unless you use this command to override the PDU lifetime with a larger value (in centi-seconds).

- **queue lifetime infinite**
  - Never drop LLC PDUs, i.e. give them an unlimited lifetime.

- **queue hysteresis <1-65535>**
  - When the downlink LLC queue is full, the PCU starts dropping packets. Using this parameter, we can set the lifetime hysteresis in centi-seconds, i.e. it will continue discarding until "lifetime - hysteresis" is reached.

- **queue codel**
  - Use the CoDel (Controlled Delay) scheduling algorithm, which is designed to overcome buffer bloat. It will use a default interval of 4 seconds.

- **queue codel interval <1-1000>**
  - Use the CoDel (Controlled Delay) scheduling algorithm, which is designed to overcome buffer bloat. Use the specified interval in centi-seconds.

- **queue idle-ack-delay <1-65535>**
  - Delay the request for an ACK after the last downlink LLC frame by the specified amount of centi-seconds.

8.5 Configuring MS power control

GPRS MS power control works completely different than the close MS power control loop in circuit-switched GSM. Rather than instructing the MS constantly about which transmit power to use, some parameters are provided to the MS by which the MS-based power control algorithm is tuned.

See 3GPP TS 05.08 for further information on the algorithm and the parameters.

You can set those parameters at the pcu VTY config node as follows:

- **gamma <0-62>**
  - Set the gamma parameter for MS power control in units of dB.

Parameter ALPHA is set on the BSC VTY configuration file on a per-BTS basis, and forwarded by OsmoPCU to the MS through the SI13 received from the former over PCUIF. OsmoPCU VTY command alpha <0-10> overrides the value received over PCUIF to keep backward compatibility with existing config files, but it is currently deprecated and its use is discouraged; one should configure it per-BTS in OsmoBSC VTY instead.
8.6 Configuring Network Assisted Cell Change (NACC)

Network Assisted Cell Change, defined in 3GPP TS 44.060 sub-clause 8.8, is a feature providing the MS aid when changing to a new cell due to autonomous reselection. In summary, the MS informs the current cell its intention to change to a new target cell, and the network decides whether to grant the intended cell change or order a change to another neighbor cell. It also provides several System Informations of the target cell to the MS to allow for quicker reselection towards it.

OsmoPCU will automatically provide the required neighbor System Information when the MS requests NACC towards a target cell also under the management of the same OsmoPCU instance, since it already has the System Information of all BTS under their control, obtained through PCUIF when the BTS registers against OsmoPCU, so no specific user configuration is required here.

In general, OsmoPCU requires to gather the information from somewhere else before being able to provide it to the MS requesting the NACC.

If OsmoPCU fails to gather the System Information, it will simply answer the MS allowing the proposed change but without previously providing the System Information of the target cell.

8.6.1 Neighbor Address Resolution

First of all, it needs to translate the <ARFCN + BSIC> identity of the target cell to change to, provided by the MS, into an identity that the Core Network can use and understand to identify the target cell, which happens to be a key composed of <RAI + Cell Identity>. This key is also named conveniently as CGI-PS, since it actually equals to the Circuit Switch CGI + RAC.

In order to apply this target cell identity translation, OsmoPCU uses the OsmoBSC Neighbor Resolution CTRL interface (see OsmoBSC User Manual), since the BSC is the node holding all the neighbor related information. By default, the use of this interface is not configured and hence disabled in OsmoPCU. As a result, until configured, the network won’t be able to provide the System Information to the MS prior to allowing the change during NACC against remote cells, which means the cell change will take longer to complete. In order to configure the interface, the OsmoBSC IP address and port to connect to must be configured in OsmoPCU VTY.

These neighbor address resolutions (<ARFCN + BSIC> ⇒ <RAI + CI>) are by default cached for a while in order to avoid querying the BSC frequently and, as a result, optimizing the resolution time too.

Example: Configure Neighbor Resolution CTRL interface against OsmoBSC

```
pCU
neighbor resolution 172.18.13.10 4248

timer X1 500

timer X0 60
```

1. Port 4248 is the default and hence could be omitted in this case
2. Time out if the BSC doesn’t answer our CTRL resolution request after 500 ms
3. Keep resolved neighbor addresses cached for 60 seconds

8.6.2 System Information Resolution

Once OsmoPCU gains knowledge of the target cell’s address in the Core Network, it can query its System Information.

OsmoPCU will gather the requested System Information of target cells under its control without need for any external query, since the System Information of all BTSs it manages are received over PCUIF and stored internally in OsmoPCU.

For those targets cells not managed by the OsmoPCU instance, the query is accomplished by using RIM procedures (NACC RAN-INFO application) over the Gb interface against the SGSN that OsmoPCU is connected to. In its turn, the SGSN will potentially forward this query to the PCU serving the target cell, which will provide back the System Information of that cell.

The System Information received from external PCUs over RIM are by default cached for a while in order to avoid querying the SGSN frequently and, as a result, optimizing the resolution time too.

Example: Configure System Information resolution
8.7 GPRS vs EGPRS considerations

8.7.1 Configuration

OsmoPCU can be configured to either:

- Allocate only GPRS TBFs to all MS (no EGPRS)
- Allocate EGPRS TBFs to EGPRS capable phones while still falling back to allocating GPRS TBFs on GPRS-only capable MS.

These two different modes of operation are selected by properly configuring the Coding Schemes (see Section 8.1.2).

The first mode of operation (GPRS-only for all MS) can be accomplished configuring OsmoPCU so that the resulting MCS set is empty. This can be done in two ways:

- Announcing an empty MCS bit-mask over PCUIF to OsmoPCU: That’s actually done automatically by OsmoBSC on BTS with VTY config set to `gprs mode gprs`.
- Configuring OsmoPCU to force an empty set by using VTY command `mcs max 0`.

Hence, if the resulting MCS bit-mask is not empty, (BSC configuring the BTS with `gprs mode egprs` and OsmoPCU VTY containing something other than `mcs max 0`), EGPRS TBFs will be allocated for all MS announcing EGPRS capabilities.

It is important to remark that in order to use MCS5-9, the BTS must support 8-PSK modulation. Nevertheless, in case 8-PSK is not supported by the BTS, one can still enable EGPRS and simply make sure 8-PSK MCS are never used by configuring OsmoPCU with `mcs max 4 4`.

Similarly, a BTS may support 8-PSK modulation only on downlink, since it is easier to implement than the uplink, together with the fact that higher downlink throughput is usually more interesting from user point of view. In this scenario, OsmoPCU can be configured to allow for full MCS range in downlink while still preventing use of 8-PSK on the uplink: `mcs max 9 4`.

Some other interesting configurations to control use of EGPRS in the network which lay outside OsmoPCU include:

- If `osmo-bts-trx` together with `osmo-trx` is used, remember to enable EGPRS support (OsmoTRX VTY `egprs enable`).
- It is possible to improve EGPRS performance (in particular, the TBF establishment timing) a bit by enabling 11-bit Access Burst support. This allows EGPRS capable phones to indicate their EGPRS capability, establishment cause, and multi-slot class directly in the Access Burst (OsmoTRX VTY `ext-rach enable`, OsmoBSC VTY `gprs egprs-packet-channel-request`).

Note

If you enable MCS5-9 you will also need an 8-PSK capable OsmoBTS+PHY, which means `osmo-bts-sysmo` or `osmo-bts-litecell15` with their associated PHY, or `osmo-bts-trx` with `osmo-trx` properly configured.
8.7.2 GPRS+EGPRS multiplexing

Both EGPRS and GPRS-only capable MS can be driven concurrently in the same PDCH timeslot by the PCU, hence no special configuration is required per timeslot regarding this topic; OsmoPCU scheduler takes care of the specific requirements when driving MS with different capabilities.

These specific requirements translate to some restrictions regarding which Coding Schemes can be used at given frame numbers, and hence which kind of RLCMAC blocks can be sent, which means serving a GPRS-only MS in a PDCH may end up affecting slightly the downlink throughput of EGPRS capable MS.

Throughput loss based on MS capabilities with TBF attached to a certain PDCH timeslot:

**All UEs are EGPRS capable**
No throughput loss, since all data is sent using EGPRS, and EGPRS control messages are used when appropriate.

**All UEs are GPRS-only (doesn’t support EGPRS)**
No throughput loss, since all data and control blocks use GPRS.

**Some UEs are GPRS-only, some EGPRS**
In general EGPRS capable UEs will use EGPRS, and GPRS-only UEs will use GPRS, with some restrictions affecting throughput of EGPRS capable UEs:

- Whenever a GPRS-only MS is to be polled to send uplink data to PCU, then a downlink RLCMAC block modulated using GMSK must be sent, which means that if the scheduler selects a EGPRS MS for downlink on that block it will force sending of data with MCS1-4 (if it’s new data, if it’s a retransmission it cannot be selected since MCS from original message cannot be changed). In the worst case if no control block needs to be sent or no new data in MCS1-4 is available to send, then an RLCMAC Dummy Block is sent.

- For synchronization purposes, each MS needs to receive an RLCMAC block which it can fully decode at least every 360ms, which means the scheduler must enforce a downlink block in CS1-4 every 360ms, that is, every 18th RLCMAC block. In general this is not a big issue since anyway all control RLCMAC blocks are encoded in CS1, so in case any control block is sent from time to time it’s accomplished and there’s no penalty. However, if only EGPRS downlink data is sent over that time frame, then the scheduler will force sending a RLCMAC Dummy Block.

9 Counters

These counters and their description based on Osmo-PCU 0.4.0.4-8d55 (Osmo-PCU).

Table 2: bssgp:bss_ctx - BSSGP Peer Statistics

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>packets:in</td>
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<td>Packets at BSSGP Level (In)</td>
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<tr>
<td>packets:out</td>
<td>[?]</td>
<td>Packets at BSSGP Level (Out)</td>
</tr>
<tr>
<td>bytes:in</td>
<td>[?]</td>
<td>Bytes at BSSGP Level (In)</td>
</tr>
<tr>
<td>bytes:out</td>
<td>[?]</td>
<td>Bytes at BSSGP Level (Out)</td>
</tr>
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<td>[?]</td>
<td>BVC Blocking count</td>
</tr>
<tr>
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<td>[?]</td>
<td>BVC LLC Discarded count</td>
</tr>
<tr>
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<td>[?]</td>
<td>BVC Status count</td>
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Table 3: ns:nsvc - NSVC Peer Statistics

<table>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>packets:in</td>
<td>[?]</td>
<td>Packets at NS Level (In)</td>
</tr>
<tr>
<td>packets:out</td>
<td>[?]</td>
<td>Packets at NS Level (Out)</td>
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</tr>
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<tr>
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<td>[?]</td>
<td>Bytes at NS Level (In)</td>
</tr>
<tr>
<td>bytes:out</td>
<td>[?]</td>
<td>Bytes at NS Level (Out)</td>
</tr>
<tr>
<td>blocked</td>
<td>[?]</td>
<td>NS-VC Block count</td>
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<tr>
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<td>NS-VC gone dead count</td>
</tr>
<tr>
<td>replaced</td>
<td>[?]</td>
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</tr>
<tr>
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<td>[?]</td>
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</tr>
<tr>
<td>inv-nsei</td>
<td>[?]</td>
<td>NSEI was invalid count</td>
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<tr>
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<td>[?]</td>
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Table 4: ns:nsvc - NSVC Peer Statistics

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</thead>
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<td>Packets at NS Level (In)</td>
</tr>
<tr>
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<td>bytes:out</td>
<td>[?]</td>
<td>Bytes at NS Level (Out)</td>
</tr>
<tr>
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<td>[?]</td>
<td>NS-VC Block count</td>
</tr>
<tr>
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<td>[?]</td>
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</tr>
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<td>replaced</td>
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<td>NS-VC replaced other count</td>
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Table 5: bts - BTS Statistics

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</tr>
<tr>
<td>tbf:dl:aborted</td>
<td>[?]</td>
<td>TBF DL Aborted</td>
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<tr>
<td>tbf:ul:alloc</td>
<td>[?]</td>
<td>TBF UL Allocated</td>
</tr>
<tr>
<td>tbf:ul:freed</td>
<td>[?]</td>
<td>TBF UL Freed</td>
</tr>
<tr>
<td>tbf:ul:aborted</td>
<td>[?]</td>
<td>TBF UL Aborted</td>
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<td>RLC DL Payload Bytes</td>
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<td>DL Assign Timeout</td>
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</tr>
<tr>
<td>pkt:dl_ack_nack_failed</td>
<td>[?]</td>
<td>PDAN poll Failed</td>
</tr>
<tr>
<td>gprs:downlink_cs1</td>
<td>[?]</td>
<td>CS1 downlink</td>
</tr>
<tr>
<td>gprs:downlink_cs2</td>
<td>[?]</td>
<td>CS2 downlink</td>
</tr>
<tr>
<td>gprs:downlink_cs3</td>
<td>[?]</td>
<td>CS3 downlink</td>
</tr>
<tr>
<td>gprs:downlink_cs4</td>
<td>[?]</td>
<td>CS4 downlink</td>
</tr>
<tr>
<td>egprs:downlink_mcs1</td>
<td>[?]</td>
<td>MCS1 downlink</td>
</tr>
<tr>
<td>egprs:downlink_mcs2</td>
<td>[?]</td>
<td>MCS2 downlink</td>
</tr>
<tr>
<td>egprs:downlink_mcs3</td>
<td>[?]</td>
<td>MCS3 downlink</td>
</tr>
<tr>
<td>egprs:downlink_mcs4</td>
<td>[?]</td>
<td>MCS4 downlink</td>
</tr>
<tr>
<td>egprs:downlink_mcs5</td>
<td>[?]</td>
<td>MCS5 downlink</td>
</tr>
<tr>
<td>egprs:downlink_mcs6</td>
<td>[?]</td>
<td>MCS6 downlink</td>
</tr>
<tr>
<td>egprs:downlink_mcs7</td>
<td>[?]</td>
<td>MCS7 downlink</td>
</tr>
<tr>
<td>egprs:downlink_mcs8</td>
<td>[?]</td>
<td>MCS8 downlink</td>
</tr>
<tr>
<td>egprs:downlink_mcs9</td>
<td>[?]</td>
<td>MCS9 downlink</td>
</tr>
</tbody>
</table>
Table 5: (continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>gprs:uplink_cs1</td>
<td>[?]</td>
<td>CS1 Uplink</td>
</tr>
<tr>
<td>gprs:uplink_cs2</td>
<td>[?]</td>
<td>CS2 Uplink</td>
</tr>
<tr>
<td>gprs:uplink_cs3</td>
<td>[?]</td>
<td>CS3 Uplink</td>
</tr>
<tr>
<td>gprs:uplink_cs4</td>
<td>[?]</td>
<td>CS4 Uplink</td>
</tr>
<tr>
<td>egprs:uplink_mcs1</td>
<td>[?]</td>
<td>MCS1 Uplink</td>
</tr>
<tr>
<td>egprs:uplink_mcs2</td>
<td>[?]</td>
<td>MCS2 Uplink</td>
</tr>
<tr>
<td>egprs:uplink_mcs3</td>
<td>[?]</td>
<td>MCS3 Uplink</td>
</tr>
<tr>
<td>egprs:uplink_mcs4</td>
<td>[?]</td>
<td>MCS4 Uplink</td>
</tr>
<tr>
<td>egprs:uplink_mcs5</td>
<td>[?]</td>
<td>MCS5 Uplink</td>
</tr>
<tr>
<td>egprs:uplink_mcs6</td>
<td>[?]</td>
<td>MCS6 Uplink</td>
</tr>
<tr>
<td>egprs:uplink_mcs7</td>
<td>[?]</td>
<td>MCS7 Uplink</td>
</tr>
<tr>
<td>egprs:uplink_mcs8</td>
<td>[?]</td>
<td>MCS8 Uplink</td>
</tr>
<tr>
<td>egprs:uplink_mcs9</td>
<td>[?]</td>
<td>MCS9 Uplink</td>
</tr>
</tbody>
</table>

NSVC Peer Statistics .ns.nsvc - NSVC Peer Statistics

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>alive.delay</td>
<td>[?]</td>
<td>ALIVE response time</td>
<td>ms</td>
</tr>
</tbody>
</table>

NSVC Peer Statistics .ns.nsvc - NSVC Peer Statistics

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>alive.delay</td>
<td>[?]</td>
<td>ALIVE response time</td>
<td>ms</td>
</tr>
</tbody>
</table>

BTS Statistics .bts - BTS Statistics

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ms.present</td>
<td>[?]</td>
<td>MS Present</td>
</tr>
</tbody>
</table>

Table 6: ungrouped osmo counters

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
</table>

10 Gb interface using libosmogb

*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 project, including OsmoSGSN, OsmoGbProxy and OsmoPCU.

This section describes the configuration that libosmogb exposes via the VTY.

10.1 Gb interface configuration

10.1.1 NS-over-UDP configuration

The GPRS-NS protocol can be encapsulated in UDP/IP. This is the default encapsulation for IP based GPRS systems.
Example: GPRS NS-over-UDP configuration

```
OsmoSGSN(config-ns)# encapsulation udp local-ip 127.0.0.1
OsmoSGSN(config-ns)# encapsulation udp local-port 23000
```

The example above configures a libosmogb based application to listen for incoming connections from PCUs on the specified address and port.

1. Set the local side IP address for NS-over-UDP
2. Set the local side UDP port number for NS-over-UDP. 23000 is the default

10.1.2 NS-over-FR-GRE configuration

The GPRS-NS protocol can alternatively be encapsulated over Frame Relay (FR). Traditionally this is communicated over SD-H/PDH media, which we don’t support. However, we can encapsulate the FR in GRE, and then that in IP.

The resulting NS-FR-GRE-IP stack can be converted by an off-the-shelf router with FR and IP support.

Example: GPRS NS-over-FR-GRE configuration

```
OsmoSGSN(config-ns)# encapsulation framerelay-gre enabled
OsmoSGSN(config-ns)# encapsulation framerelay-gre local-ip 127.0.0.1
```

1. Enable FR-GRE encapsulation
2. Set the local side IP address for NS-over-FR-GRE

10.1.3 NS Timer configuration

The NS protocol features a number of configurable timers.

Table 7: List of configurable NS timers

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tns-block</td>
<td>(un)blocking timer timeout (secs)</td>
</tr>
<tr>
<td>tns-block-retries</td>
<td>(un)blocking timer; number of retries</td>
</tr>
<tr>
<td>tns-reset</td>
<td>reset timer timeout (secs)</td>
</tr>
<tr>
<td>tns-reset-retries</td>
<td>reset timer; number of retries</td>
</tr>
<tr>
<td>tns-test</td>
<td>test timer timeout (secs)</td>
</tr>
<tr>
<td>tns-alive</td>
<td>alive timer timeout(secs)</td>
</tr>
<tr>
<td>tns-alive-retries</td>
<td>alive timer; number of retries</td>
</tr>
</tbody>
</table>

10.2 Examining Gb interface status

There are several commands that can help to inspect and analyze the currently running system status with respect to the Gb interfaces.

Example: Inspecting NS state

```
OsmoSGSN> show ns
Encapsulation NS-UDP-IP       Local IP: 127.0.0.1, UDP Port: 23000
Encapsulation NS-FR-GRE-IP    Local IP: 0.0.0.0
```

Example: Inspecting NS statistics
OsmoPCU User Manual

OsmoSGSN> show ns stats
Encapsulation NS-UDP-IP  Local IP: 10.9.1.198, UDP Port: 23000
Encapsulation NS-FR-GRE-IP  Local IP: 0.0.0.0
NSEI 101, NS-VC 101, Remote: BSS, ALIVE UNBLOCKED, UDP 10.9.1.119:23000
NSVC Peer Statistics:
  Packets at NS Level (In): 1024 (2/s 123/m 911/h 0/d)
  Packets at NS Level (Out): 1034 (0/s 151/m 894/h 0/d)
  Bytes at NS Level (In): 296638 (1066/s 22222/m 274244/h 0/d)
  Bytes at NS Level (Out): 139788 (0/s 48225/m 91710/h 0/d)
  NS-VC Block count : 0 (0/s 0/m 0/h 0/d)
  NS-VC gone dead count : 0 (0/s 0/m 0/h 0/d)
  NS-VC replaced other count: 0 (0/s 0/m 0/h 0/d)
  NS-VC changed NSEI count : 0 (0/s 0/m 0/h 0/d)
  NS-VCI was invalid count : 0 (0/s 0/m 0/h 0/d)
  NSEI was invalid count : 0 (0/s 0/m 0/h 0/d)
  ALIVE ACK missing count : 0 (0/s 0/m 0/h 0/d)
  RESET ACK missing count : 0 (0/s 0/m 0/h 0/d)
NSVC Peer Statistics:
  ALIVE response time : 0 ms

Example: Inspecting BSSGP state

OsmoSGSN> show bssgp
NSEI 101, BVCI 2, RA-ID: 1-2-1-0, CID: 0, STATE: UNBLOCKED
NSEI 101, BVCI 0, RA-ID: 0-0-0-0, CID: 0, STATE: UNBLOCKED

FIXME: show nse

10.3 FIXME

10.3.1 Blocking / Unblocking / Resetting NS Virtual Connections

The user can manually perform operations on individual NSVCs:

- blocking a NSVC
- unblocking a NSVC
- resetting a NSVC

The VTY command used for this is the \texttt{nsvc (nsei|nsvci) <0-65535> (block|unblock|reset)} command available from the ENABLE node.

10.4 Gb interface logging filters

There are some Gb-interface specific filters for the libosmocore logging subsystem, which can help to reduce the logged output to messages pertaining to a certain NS or BSSGP connection only.

Example: enabling a log filter for a given NSEI

OsmoSGSN> logging filter nsvc nsei 23

Example: enabling a log filter for a given NSVCI

OsmoSGSN> logging filter nsvc nsvci 23

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11 QoS, DSCP/TOS, Priority and IEEE 802.1q PCP

In many use cases operators want to apply different QoS classes for user plane vs. control plane traffic. IP Routers, Ethernet switches and other network gear can then perform intelligent queue management as required for the respective service.

For example, voice user plane frames need a rather stable and short latency, while IP user plane and control plane traffic has less critical latency requirements.

11.1 IP Level (DSCP)

At IP level, different priorities / classes of traffic are expressed in accordance to [ietf-rfc2474] by the DSCP (Differentiated Services Code Point) field of the IP header. DSCP resembles the upper 6 bits of the field formerly known as the TOS bits as per [ietf-rfc791].

On Linux and other operating systems with BSD-style sockets API, the applications can request a specific DSCP value to be used for packets generated by those sockets.

Osmocom CNI software such as osmo-bts and osmo-mgw support setting the DSCP value via VTY commands, see e.g. the rtp ip-dscp setting of the bts node in osmo-bts.

11.2 Packet Priority

In the Linux network stack, every packet is represented by struct sk_buff, which has an associated priority. Furthermore, every socket through which applications send data have an associated socket priority. Each time a packet is transmitted through a given socket, the packet inherits the packet priority from the socket priority.

Furthermore, there is a mapping table that maps DSCP/TOS bits to priority. The sixteen different TOS bit values are mapped to priority values as follows:

<table>
<thead>
<tr>
<th>TOS (binary)</th>
<th>DSCP (binary)</th>
<th>Priority (decimal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>xxx0000x</td>
<td>xxx000</td>
<td>0</td>
</tr>
<tr>
<td>xxx0001x</td>
<td>xxx000</td>
<td>0</td>
</tr>
<tr>
<td>xxx0010x</td>
<td>xxx001</td>
<td>0</td>
</tr>
<tr>
<td>xxx0011x</td>
<td>xxx001</td>
<td>0</td>
</tr>
<tr>
<td>xxx0100x</td>
<td>xxx010</td>
<td>2</td>
</tr>
<tr>
<td>xxx0101x</td>
<td>xxx010</td>
<td>2</td>
</tr>
<tr>
<td>xxx0110x</td>
<td>xxx011</td>
<td>2</td>
</tr>
<tr>
<td>xxx0111x</td>
<td>xxx011</td>
<td>2</td>
</tr>
<tr>
<td>xxx1000x</td>
<td>xxx100</td>
<td>6</td>
</tr>
<tr>
<td>xxx1001x</td>
<td>xxx100</td>
<td>6</td>
</tr>
<tr>
<td>xxx1010x</td>
<td>xxx101</td>
<td>6</td>
</tr>
<tr>
<td>xxx1011x</td>
<td>xxx101</td>
<td>6</td>
</tr>
<tr>
<td>xxx1100x</td>
<td>xxx110</td>
<td>4</td>
</tr>
<tr>
<td>xxx1101x</td>
<td>xxx110</td>
<td>4</td>
</tr>
<tr>
<td>xxx1110x</td>
<td>xxx111</td>
<td>4</td>
</tr>
<tr>
<td>xxx1111x</td>
<td>xxx111</td>
<td>4</td>
</tr>
</tbody>
</table>

This table of default DSCP/TOS → priority bit mappings cannot be modified.

However, the per-packet priority values can be set by various means of network policy, including
• by packet filter rules (iptables, ip6tables, nftables)
  – if you use iptables, using "CLASSIFY --set-class in the mangle table"
  – if you use nftables, using "meta priority set in the mangle table"
• by the application using the SO_PRIORITY socket option (currently not yet supported by Osmocom CNI)

11.3 Ethernet Level (PCP)

At Ethernet level, different priorities / QoS classes are expressed by the so-called PCP (Priority Code Point) field in the IEEE 802.1q (VLAN) header.

NOTE
This means that PCP functionality requires the use of IEEE 802.1q VLAN. You cannot use PCP without VLAN.

The Linux kernel assigns IEEE 802.1q PCP bits based on a mapping between the priority and the PCP value. Each VLAN network device maintains a separate map for both egress (transmit) and ingress (receive) path.

The current priority mappings can be inspected via the /proc filesystem. For example, if you have a VLAN device eth0.9 for VLAN ID 9 on the net-device eth0, you can use the following example:

Example: Inspecting the current egress QoS map

```bash
$ sudo cat /proc/net/vlan/eth0.9
eth0.9 VID: 9 REORDER_HDR: 1 dev->priv_flags: 1021
  total frames received 123340
  total bytes received 40668066
  Broadcast/Multicast Rcvd 1106
  total frames transmitted 10499
  total bytes transmitted 1570809
Device: eth0
INGRESS priority mappings: 0:0 1:0 2:0 3:0 4:0 5:0 6:0 7:0
EGRESS priority mappings: 1:1 2:2 3:3
```

1. make sure to specify your specific VLAN interface name here instead of eth0.9
2. ingress priority mappings (all PCP values mapped to priority 0)
3. egress priority mappings (empty)

As we can see in the above example, there are no egress priority mappings yet. Let’s create three new mappings, mapping priority value 1 to PCP 1, priority 2 to PCP 2, and priority 3 to PCP 3:

Example: Creating three new egress QoS mappings

```bash
$ sudo ip link set dev eth0.9 type vlan egress-qos-map 1:1 2:2 3:3
$ sudo cat /proc/net/vlan/eth0.9
eth0.9 VID: 9 REORDER_HDR: 1 dev->priv_flags: 1021
  total frames received 123898
  total bytes received 40843611
  Broadcast/Multicast Rcvd 1106
  total frames transmitted 10517
  total bytes transmitted 1574357
Device: eth0
INGRESS priority mappings: 0:0 1:0 2:0 3:0 4:0 5:0 6:0 7:0
EGRESS priority mappings: 1:1 2:2 3:3
```
make sure to specify your specific VLAN interface name here instead of `eth0.9`

call command to define three new egress QoS maps

call command to re-display the current status

tree new egress mappings are shown as given in `ip` command

**NOTE**
The settings of the `ip` command are volatile and only active until the next reboot (or the network device or VLAN is removed). Please refer to the documentation of your specific Linux distribution in order to find out how to make such settings persistent by means of an `ifup` hook whenever the interface comes up. For CentOS/RHEL 8 this can e.g. be achieved by means of an `/sbin/ifup-local` script (when using `network-scripts` and not NetworkManager). For Debian or Ubuntu, this typically involves adding `up` lines to `/etc/network/interfaces` or a `/etc/network/if-up.d` script.

### 11.4 Putting things together

Assuming one needs to set both the DSCP bits as well as the PCP for certain traffic, the above-mentioned mechanisms need to be combined as follows:

1. configure the osmocom program to set the DSCP value
2. use the default DSCP $\rightarrow$ priority mapping, if possible
3. configure an egress QoS map to map from priority to PCP

If the desired combination of DSCP + PCP cannot be achieved that way, due to the rather static default kernel mapping table, one needs to go one step further:

1. configure the osmocom program to set the DSCP value
2. use packet filter rules to set the priority based on DSCP
3. configure an egress QoS map to map from priority to PCP

#### 11.4.1 Full example of QoS for osmo-pcu uplink QoS

In the below example we will show the full set of configuration required for both DSCP and PCP differentiation of uplink Gb traffic by osmo-pcu.

What we want to achieve in this example is the following configuration:

<table>
<thead>
<tr>
<th>Traffic</th>
<th>DSCP</th>
<th>PCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gb (NS)</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

1. configure the osmocom program to set the DSCP value
   - `osmo-pcu.cfg: dscp 10 in udp bind vty node`
2. configure an egress QoS map to map from priority to PCP
Example Step 1: add related VTY configuration to osmo-pcu.cfg

```plaintext
...  
pcu  
gb ip-dscp 10  
gb socket-priority 1  
...  
```

Example Step 2: egress QoS map to map from DSCP values to priority values

```plaintext
$ sudo ip link set dev eth0.9 type vlan egress-qos-map 0:0 1:1 5:5 6:6 7:7
```

- make sure to specify your specific VLAN interface name here instead of eth0.9.
- create an egress QoS map that maps the priority value 1:1 to the PCP. We also include the mappings for 5, 6, and 7 from the osmo-bts example here (see [userman-osmobts]).

**NOTE**
The settings of the `ip` command are volatile and only active until the next reboot (or the network device or VLAN is removed). Please refer to the documentation of your specific Linux distribution in order to find out how to make such settings persistent by means of an `ifup` hook whenever the interface comes up. For CentOS/RHEL 8 this can e.g. be achieved by means of an `/sbin/ifup-local` script (when using `network-scripts` and not NetworkManager). For Debian or Ubuntu, this typically involves adding `up` lines to `/etc/network/interfaces` or a `/etc/network/if-up.d` script.

## 12 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.

### 12.1 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**

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

- Configure process to use `SCHED_RR` policy with real time priority 1

### 12.2 CPU-Affinity Mask

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

The set of CPUs where each thread is allowed to run on is expressed by means of a bitmask in hexadecimal representation, where the right most bit relates to CPU 0, and the Nth most significant bit relates to CPU N-1. Setting the bit means the process is allowed to run on that CPU, while clearing it means the process is forbidden to run on that CPU.
Hence, for instance a cpu-affinity mask of 0x00 means the thread is not allowed on any CPU, which will cause the thread to stall until a new value is applied. A mask of 0x01 means the thread is only allowed to run on the 1st CPU (CPU 0). A mask of 0xff00 means CPUs 8-15 are allowed, while 0-7 are not.

For single-threaded processes (most of Osmocom are), it is usually enough to set this line in VTY config file as follows:

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

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

Or otherwise:

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

- Allow all threads only on CPU 0

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

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

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

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

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

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

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

- Allow thread named TxLower (338635) only on CPU 1
- Allow with TID 338636 (RxLower) only on CPU 0 and 1

Since thread names are set dynamically by the process during startup or at a later point after creating the thread itself, One may need to specify in the config file that the mask must be applied by the thread itself once being configured rather than trying to apply it immediately. To specify so, the delay keyword is used 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
```

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

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

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

3GPP
3rd Generation Partnership Project

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

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

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

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

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

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

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

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

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

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

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

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

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

BTS
Base Transceiver Station

BSC
Base Station Controller

BSIC
Base Station Identity Code; 16bit identifier of BTS within location area
BSSGP
Base Station Subsystem Gateway Protocol (3GPP TS 48.018 [3gpp-ts-48-018])

BVCI
BSSGP Virtual Circuit Identifier

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

CC
Call Control; Part of the GSM Layer 3 Protocol

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

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

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

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

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

dB
deci-Bel; relative logarithmic unit

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

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

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

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

DSP
Digital Signal Processor
dvnixload
Tool to program UBL and the Bootloader on a sysmoBTS

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

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

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

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

ETSI
European Telecommunications Standardization Institute
FPGA  
Field Programmable Gate Array; programmable digital logic hardware

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

GERAN  
GPRS/EDGE Radio Access Network

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

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

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

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

Gp  
Gp interface between SGSN and GGSN; uses GTP protocol

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

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

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

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

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

GT  
Global Title; an address in SCCP

GTP  
GPRS Tunnel Protocol; used between SGSN and GGSN

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

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

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

IE  
Information Element

IMEI  
International Mobile Equipment Identity; unique 14-digit decimal number to globally identify a mobile device, optionally with a 15th checksum digit

IMEISV  
IMEI software version; unique 14-digit decimal number to globally identify a mobile device (same as IMEI) plus two software version digits (total digits: 16)
IMSI
International Mobile Subscriber Identity; 15-digit unique identifier for the subscriber/SIM; starts with MCC/MNC of issuing operator

IP
Internet Protocol (IETF RFC 791 [ietf-rfc791])

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

Iu
Interface in 3G/UMTS between RAN and CN

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

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

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

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

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

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

Location Area
Location Area; a geographic area containing multiple BTS

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

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

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

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

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

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

MGW
Media Gateway

MM
Mobility Management; part of the GSM Layer 3 Protocol

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

MNCC
Mobile Network Call Control; Unix domain socket based Interface between MSC and external call control entity like osmo-sip-connector
MNO
Mobile Network Operator; operator with physical radio network under his MCC/MNC

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

MS
Mobile Station; a mobile phone / GSM Modem

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

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

MSISDN
Mobile Subscriber ISDN Number; telephone number of the subscriber

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

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

MVNO
Mobile Virtual Network Operator; Operator without physical radio network

NCC
Network Color Code; assigned by national regulator

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

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

NSEI
NS Entity Identifier

NVCI
NS Virtual Circuit Identifier

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

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

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

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

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

OpenGGSN
Open Source implementation of a GPRS Packet Control Unit
OpenVPN
Open-Source Virtual Private Network; software employed to establish encrypted private networks over untrusted public networks

Osmocom
Open Source MOBILE 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

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

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

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

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

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

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

RF
Radio Frequency

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

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

RR
Radio Resources; Part of the GSM Layer 3 Protocol

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

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

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

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

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

SDK
Software Development Kit

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

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

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

SIM
Subscriber Identity Module; small chip card storing subscriber identity

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

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

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

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 \((IETF RFC 768 [ietf-rfc768])\)

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>
<thead>
<tr>
<th>L4 Protocol</th>
<th>Port Number</th>
<th>Purpose</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDP</td>
<td>2427</td>
<td>MGCP GW</td>
<td>osmo-bsc_mgcp, osmo-mgw</td>
</tr>
<tr>
<td>TCP</td>
<td>2775</td>
<td>SMPP (SMS interface for external programs)</td>
<td>osmo-nitb</td>
</tr>
<tr>
<td>TCP</td>
<td>3002</td>
<td>A-bis/IP OML</td>
<td>osmo-bts, osmo-bsc, osmo-nitb</td>
</tr>
<tr>
<td>TCP</td>
<td>3003</td>
<td>A-bis/IP RSL</td>
<td>osmo-bts, osmo-bsc, osmo-nitb</td>
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<tr>
<td>TCP</td>
<td>4227</td>
<td>telnet (VTY)</td>
<td>osmo-pcap-client</td>
</tr>
<tr>
<td>TCP</td>
<td>4228</td>
<td>telnet (VTY)</td>
<td>osmo-pcap-server</td>
</tr>
<tr>
<td>TCP</td>
<td>4236</td>
<td>Control Interface</td>
<td>osmo-trx</td>
</tr>
<tr>
<td>TCP</td>
<td>4237</td>
<td>telnet (VTY)</td>
<td>osmo-trx</td>
</tr>
<tr>
<td>TCP</td>
<td>4238</td>
<td>Control Interface</td>
<td>osmo-bts</td>
</tr>
<tr>
<td>TCP</td>
<td>4239</td>
<td>telnet (VTY)</td>
<td>osmo-stp</td>
</tr>
<tr>
<td>TCP</td>
<td>4240</td>
<td>telnet (VTY)</td>
<td>osmo-pcu</td>
</tr>
<tr>
<td>TCP</td>
<td>4241</td>
<td>telnet (VTY)</td>
<td>osmo-bts</td>
</tr>
<tr>
<td>TCP</td>
<td>4242</td>
<td>telnet (VTY)</td>
<td>osmo-nitb, osmo-bsc, cellmgr-ng</td>
</tr>
<tr>
<td>TCP</td>
<td>4243</td>
<td>telnet (VTY)</td>
<td>osmo-bsc_mgcp, osmo-mgw</td>
</tr>
<tr>
<td>TCP</td>
<td>4244</td>
<td>telnet (VTY)</td>
<td>osmo-bsc_nat</td>
</tr>
<tr>
<td>TCP</td>
<td>4245</td>
<td>telnet (VTY)</td>
<td>osmo-sgsn</td>
</tr>
<tr>
<td>TCP</td>
<td>4246</td>
<td>telnet (VTY)</td>
<td>osmo-gpproxy</td>
</tr>
<tr>
<td>TCP</td>
<td>4247</td>
<td>telnet (VTY)</td>
<td>OsmocomBB</td>
</tr>
<tr>
<td>TCP</td>
<td>4249</td>
<td>Control Interface</td>
<td>osmo-nitb, osmo-bsc</td>
</tr>
<tr>
<td>TCP</td>
<td>4250</td>
<td>Control Interface</td>
<td>osmo-bsc_nat</td>
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<td>TCP</td>
<td>4251</td>
<td>Control Interface</td>
<td>osmo-sgsn</td>
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<tr>
<td>TCP</td>
<td>4252</td>
<td>telnet (VTY)</td>
<td>symobts-mgr</td>
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<tr>
<td>TCP</td>
<td>4253</td>
<td>telnet (VTY)</td>
<td>osmo-gtphub</td>
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<tr>
<td>TCP</td>
<td>4254</td>
<td>telnet (VTY)</td>
<td>osmo-msc</td>
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<tr>
<td>TCP</td>
<td>4255</td>
<td>Control Interface</td>
<td>osmo-msc</td>
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<tr>
<td>TCP</td>
<td>4256</td>
<td>telnet (VTY)</td>
<td>osmo-sip-connector</td>
</tr>
<tr>
<td>TCP</td>
<td>4257</td>
<td>Control Interface</td>
<td>osmo-ggsn, ggsn (OpenGGSN)</td>
</tr>
<tr>
<td>TCP</td>
<td>4258</td>
<td>telnet (VTY)</td>
<td>osmo-hlr</td>
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<tr>
<td>TCP</td>
<td>4259</td>
<td>Control Interface</td>
<td>osmo-hlr</td>
</tr>
<tr>
<td>TCP</td>
<td>4260</td>
<td>telnet (VTY)</td>
<td>osmo-ggsn</td>
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</table>
Table 10: (continued)

<table>
<thead>
<tr>
<th>L4 Protocol</th>
<th>Port Number</th>
<th>Purpose</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP</td>
<td>4261</td>
<td>telnet (VTY)</td>
<td>osmo-hnbgw</td>
</tr>
<tr>
<td>TCP</td>
<td>4262</td>
<td>Control Interface</td>
<td>osmo-hnbgw</td>
</tr>
<tr>
<td>TCP</td>
<td>4263</td>
<td>Control Interface</td>
<td>osmo-gbproxy</td>
</tr>
<tr>
<td>TCP</td>
<td>4264</td>
<td>telnet (VTY)</td>
<td>osmo-cbc</td>
</tr>
<tr>
<td>TCP</td>
<td>4265</td>
<td>Control Interface</td>
<td>osmo-cbc</td>
</tr>
<tr>
<td>TCP</td>
<td>4266</td>
<td>D-GSM MS Lookup: mDNS serve</td>
<td>osmo-hlr</td>
</tr>
<tr>
<td>TCP</td>
<td>4267</td>
<td>Control Interface</td>
<td>osmo-mgw</td>
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<tr>
<td>TCP</td>
<td>4268</td>
<td>telnet (VTY)</td>
<td>osmo-uecups</td>
</tr>
<tr>
<td>SCTP</td>
<td>4268</td>
<td>UECUPS</td>
<td>osmo-uecups</td>
</tr>
<tr>
<td>TCP</td>
<td>4269</td>
<td>telnet (VTY)</td>
<td>osmo-e1d</td>
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<tr>
<td>TCP</td>
<td>4271</td>
<td>telnet (VTY)</td>
<td>osmo-smic</td>
</tr>
<tr>
<td>TCP</td>
<td>4272</td>
<td>Control Interface</td>
<td>osmo-smic</td>
</tr>
<tr>
<td>UDP</td>
<td>4729</td>
<td>GSMTAP</td>
<td>Almost every osmocom project</td>
</tr>
<tr>
<td>TCP</td>
<td>5000</td>
<td>A/IP</td>
<td>osmo-bsc, osmo-bsc_nat</td>
</tr>
<tr>
<td>UDP</td>
<td>23000</td>
<td>GPRS-NS over IP default port</td>
<td>osmo-pcu, osmo-sgsn, osmo-gbproxy</td>
</tr>
</tbody>
</table>

B Bibliography / References

B.0.0.0.1 References


[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


[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


[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

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

[58] [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


[61] [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

[62] [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

[63] [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

[64] [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

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


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

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