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OsmoMGW User Manual

by Daniel Willmann

DRAFT

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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**
1.1 Acknowledgements . . . 1
1.2 Endorsements . . . 2

2 Preface **2**
2.1 FOSS lives by contribution! . . . 2
2.2 Osmocom and sysmocom . . . 3
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 . . . 4
2.4.5 Documentation License . . . 4

3 Introduction **4**
3.1 Required Skills . . . 4
3.2 Getting assistance . . . 5

4 Overview **5**
4.1 About OsmoMGW . . . 5
4.2 Software Components . . . 6
4.2.1 MGCP Implementation . . . 6
4.2.2 RTP implementation . . . 6
4.2.3 Audio transcoder . . . 6
4.3 Limitations . . . 6
4.4 Additional resources . . . 6

5 Running OsmoMGW **7**
5.1 SYNOPSIS . . . 7
5.2 OPTIONS . . . 7
5.3 Configure limits . . . 7

6 The Osmocom VTY Interface **7**
6.1 Accessing the telnet VTY . . . 8
6.2 VTY Nodes . . . 9
6.3 Interactive help . . . 9
6.3.1 The question-mark (`?`) command . . . 9
6.3.2 TAB completion . . . 11
6.3.3 The `list` command . . . 11
6.3.4 The attribute system . . . 13
6.3.5 The expert mode . . . 14

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7 libosmocore Logging System **15**
7.1 Log categories . . . 15
7.2 Log levels . . . 15
7.3 Log printing options . . . 16
7.4 Log filters . . . 16
7.5 Log targets . . . 17
7.5.1 Logging to the VTY . . . 17
7.5.2 Logging to the ring buffer . . . 17
7.5.3 Logging via gsmtap . . . 17
7.5.4 Logging to a file . . . 19
7.5.5 Logging to syslog . . . 20
7.5.6 Logging to systemd-journal . . . 21
7.5.7 Logging to stderr . . . 22

8 Configuring OsmoMGW **22**
8.1 Configuring MGCP . . . 22
8.2 Configuring the trunk . . . 23
8.3 E1 trunk considerations . . . 23

9 MGCP Endpoints **25**
9.1 RTP proxy / RTP bridge endpoints . . . 25
9.2 E1/T1 endpoints . . . 25
9.3 The `null` endpoint . . . 26

10 MGCP Extensions **26**
10.1 `X-Osmo-IGN` . . . 26
10.1.1 `X-Osmo-IGN` Format . . . 26
10.1.2 Supported `X-Osmo-IGN` Items . . . 27
10.1.2.1 `X-Osmo-IGN: C` . . . 27
10.2 `X-Osmux` . . . 27
10.3 Non-standard SDP codec parameters . . . 27
10.3.1 `tw-ts-001` parameter for FR and EFR codecs . . . 28
10.3.2 `tw-ts-002` parameter for HR codec . . . 28

11 Osmux **28**
11.1 Osmux and NAT . . . 29
11.2 CID allocation . . . 29
11.3 3GPP AoIP network setup with Osmux . . . 30
11.4 SCCPLite network setup with Osmux . . . 32
11.5 SCCPLite network setup with Osmux + BSC-NAT . . . 34

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11.6 Osmux and MGCP . . . 36
11.6.1 X-Osmux Format . . . 36
11.6.2 X-Osmux Considerations . . . 36
11.6.3 X-Osmux Support . . . 37
11.7 Abis setup with Osmux . . . 37

12 QoS, DSCP/TOS, Priority and IEEE 802.1q PCP 38
12.1 IP Level (DSCP) . . . 38
12.2 Packet Priority . . . 39
12.3 Ethernet Level (PCP) . . . 39
12.4 Putting things together . . . 41
12.4.1 Full example of QoS for osmo-mgw . . . 41

13 VTY Process and Thread management 42
13.1 Scheduling Policy . . . 42
13.2 CPU-Affinity Mask . . . 42

14 Glossary 43

A Osmocom TCP/UDP Port Numbers 52

B Bibliography / References 53
B.0.0.0.1 References . . . 53

C GNU Free Documentation License 57
C.1 PREAMBLE . . . 58
C.2 APPLICABILITY AND DEFINITIONS . . . 58
C.3 VERBATIM COPYING . . . 59
C.4 COPYING IN QUANTITY . . . 59
C.5 MODIFICATIONS . . . 59
C.6 COMBINING DOCUMENTS . . . 60
C.7 COLLECTIONS OF DOCUMENTS . . . 61
C.8 AGGREGATION WITH INDEPENDENT WORKS . . . 61
C.9 TRANSLATION . . . 61
C.10 TERMINATION . . . 61
C.11 FUTURE REVISIONS OF THIS LICENSE . . . 62
C.12 RELICENSING . . . 62
C.13 ADDENDUM: How to use this License for your documents . . . 62

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1 Foreword

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

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

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

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

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

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

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

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

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

1.1 Acknowledgements

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

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

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

May the source be with you!

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

1.2 Endorsements

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

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

2 Preface

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

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

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

2.1 FOSS lives by contribution!

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

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

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

We're looking forward to receiving your contributions.

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2.2 Osmocom and sysmocom

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

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

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

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

2.3 Corrections

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

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

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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.

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

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

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2.4.5 Documentation License

Please see Appendix C for further information.

3 Introduction

3.1 Required Skills

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

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

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

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

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

Some of the useful skills we recommend are:

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

3.2 Getting assistance

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

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

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

4 Overview

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

4.1 About OsmoMGW

OsmoMGW is the Osmocom implementation of a media gateway to handle user plane (voice) traffic in cellular networks. It can connect and optionally transcode RTP voice streams between different network elements such as BTSs and external entities like SIP. It is typically co-located with both OsmoBSC and OsmoMSC and controlled by them via MGCP, the Media Gateway Control Protocol.

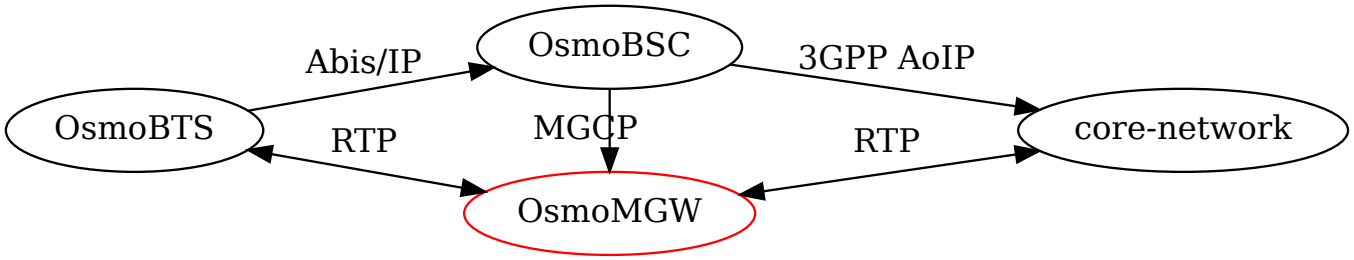

Figure 1: OsmoMGW used with OsmoBSC

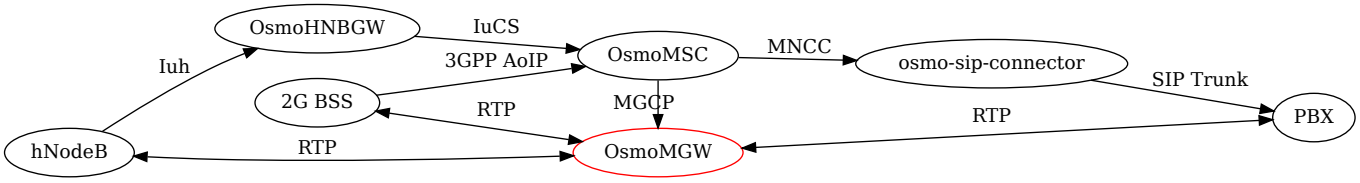

Figure 2: OsmoMGW used with OsmoMSC

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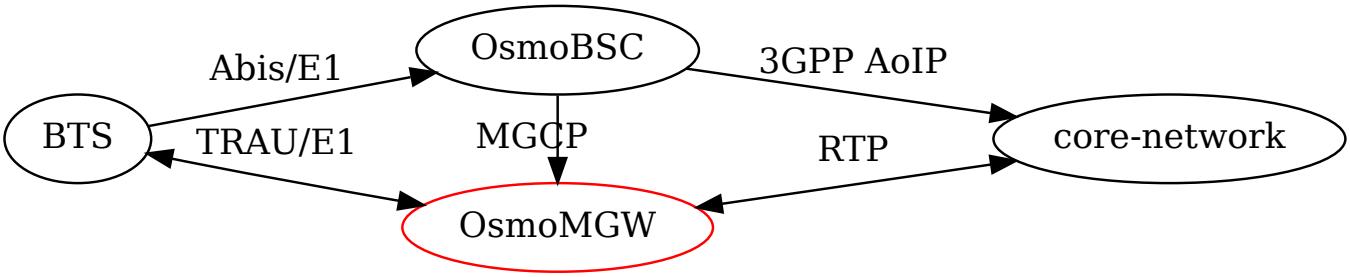

Figure 3: Integration of legacy E1 BTS in AoIP network

4.2 Software Components

OsmoMGW contains a variety of different software components, which we'll quickly describe in this section.

4.2.1 MGCP Implementation

OsmoMGW brings its own MGCP implementation through which OsmoMGW is controlled.

The commands implemented are CRCX, MDCX, DLCX and RSIP. The command AUEP is implemented as a stub and will simply respond with OK.

4.2.2 RTP implementation

Support for IuUP which is used in 3G cells is quite lacking at the moment. 3G<→3G and 2G<→2G calls should work, but 3G<→2G does not.

4.2.3 Audio transcoder

Transcoding is currently not supported in OsmoMGW.

4.3 Limitations

At the moment (November 2020), OsmoMGW implements RTP proxy / RTP bridge type endpoints and E1/T1 16k/8k sub-slots with TRAU frames for classic BTS support. To the RTP proxy / RTP bridge endpoints two RTP connections can be established, which then work as a tandem. E1/T1 endpoints support one RTP connection at a time that is associated with a sub-slot on an E1 line. We are planning to add further endpoint types for:

- classic E1/T1 timeslots (64kBps alaw/ulaw)
- announcement/playout end-points
- conference endpoints

4.4 Additional resources

You can find the OsmoMGW issue tracker and wiki online at

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

RFC 3435 for MGCP is located at

- https://tools.ietf.org/html/rfc3435

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5 Running OsmoMGW

The OsmoMGW executable (`osmo-mgw`) offers the following command-line arguments:

5.1 SYNOPSIS

osmo-mgw [-hl-V] [-D] [-c *CONFIGFILE*] [-s]

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-mgw.cfg` in the current working directory.

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

5.3 Configure limits

When servicing hundreds of media endpoints, it may be necessary to adjust the operating system's limit on open file descriptors for the osmo-mgw process. A typical default limit imposed by operating systems is 1024; this would be exceeded by, for example, about 256 active voice calls with 4 RTP/RTPC ports each, sockets for other interfaces not considered yet.

It should be ok to set an OS limit on open file descriptors as high as 65536 for osmo-mgw, which practically rules out failure from running out of file descriptors anywhere (<16,000 active calls).

When using systemd, the file descriptor limit may be adjusted in the service file by the `LimitNOFILE` setting ("Number of Open FILE descriptors"). OsmoMGW ships a systemd service file with a high LimitNOFILE setting.

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

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

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

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

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

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

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

Table 1: VTY Parameter Patterns

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

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.

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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

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

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

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

Example: Typing ? after a partial command

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

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

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

Example: Typing ? after show bsc

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

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

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6.3.2 TAB completion

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

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

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

❶ Type `<tab>` here.

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

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

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

❶ Type `<tab>` here.

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> sccp addressbook
  show cs7 instance <0-15> sccp users
  show cs7 instance <0-15> sccp ssn <0-65535>
  show cs7 instance <0-15> sccp connections
  show cs7 instance <0-15> sccp timers
  logging enable
  logging disable
  logging filter all (0|1)
  logging color (0|1)
  logging timestamp (0|1)
  logging print extended-timestamp (0|1)
  logging print category (0|1)
  logging print category-hex (0|1)
  logging print level (0|1)
  logging print file (0|1|basename) [last]
```

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```
  logging set-log-mask MASK
  logging level (rll|cc|mm|rr|mncc|pag|msc|mgcp|ho|db|ref|ctrl|smpp|ranap|vlr|iucs|bssap| ↩
      sgs|lglobal|llapd|linp|lmux|lmi|lmib|lsms|lctrl|lgtp|lstats|lgsup|loap|lss7|lsccp|lsua ↩
      |lm3ua|lmgcp|ljibuf|lrspro) (debug|info|notice|error|fatal)
  logging level set-all (debug|info|notice|error|fatal)
  logging level force-all (debug|info|notice|error|fatal)
  no logging level force-all
  show logging vty
  show alarms
  show talloc-context (application|all) (full|brief|DEPTH)
  show talloc-context (application|all) (full|brief|DEPTH) tree ADDRESS
  show talloc-context (application|all) (full|brief|DEPTH) filter REGEXP
  show stats
  show stats level (global|peer|subscriber)
  show asciidoc counters
  show rate-counters
  show fsm NAME
  show fsm all
  show fsm-instances NAME
  show fsm-instances all
  show sgs-connections
  show subscriber (msisdn|extension|imsi|tmsi|id) ID
  show subscriber cache
  show bsc
  show connection
  show transaction
  sms send pending
  sms delete expired
  subscriber create imsi ID
  subscriber (msisdn|extension|imsi|tmsi|id) ID sms sender (msisdn|extension|imsi|tmsi|id)  ↩
      SENDER_ID send .LINE
  subscriber (msisdn|extension|imsi|tmsi|id) ID silent-sms sender (msisdn|extension|imsi| ↩
      tmsi|id) SENDER_ID send .LINE
  subscriber (msisdn|extension|imsi|tmsi|id) ID silent-call start (any|tch/f|tch/any|sdcch)
  subscriber (msisdn|extension|imsi|tmsi|id) ID silent-call stop
  subscriber (msisdn|extension|imsi|tmsi|id) ID ussd-notify (0|1|2) .TEXT
  subscriber (msisdn|extension|imsi|tmsi|id) ID ms-test close-loop (a|b|c|d|e|f|i)
  subscriber (msisdn|extension|imsi|tmsi|id) ID ms-test open-loop
  subscriber (msisdn|extension|imsi|tmsi|id) ID paging
  show statistics
  show sms-queue
  logging filter imsi IMSI
  show smpp esme
```

Tip

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

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

```
OsmoMSC(config-net)# list
  help
  list
  write terminal
  write file
  write memory
  write
  show running-config
```

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

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 implemets a system of attribute flags, which can be displayed using the `show` command with the parameter `vty-attributes`

Example: Typing show vty-attributes at the VTY prompt

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

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

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

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

Example: Typing list with-flags at the VTY prompt

```
OsmoBSC(config-net-bts)# list with-flags
  . ...  help
  . ...  list [with-flags]
  . ...  show vty-attributes
  . ...  show vty-attributes (application|library|global)
```

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

❶ This command has no attributes assigned.

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

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

❹, ❺ This command applies immediately.

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

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

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

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

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

❶ This command enables the *expert* mode.

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

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

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 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.

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

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

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

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

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

Afterwards you can adjust specific categories as usual.

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

7.3 Log printing options

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

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

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

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

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

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

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

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

7.4 Log filters

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

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

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

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

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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

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

GSMTAP logging is now a method how Osmocom software can also encapsulate its own log output in GSMTAP frames. We're not trying to re-invent rsyslog here, but this is very handy When debugging complex issues. It enables the reader of the pcap file

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containing GSMTAP logging together with other protocol traces to reconstruct exact chain of events. A single pcap file can then contain both the log output of any number of Osmocom programs in the same timeline of the messages on various interfaces in and out of said Osmocom programs.

It's configured as follows:

```
OsmoBSC> enable
OsmoBSC# configure terminal
OsmoBSC(config)# log gsmtap 192.168.2.3 (1)
OsmoBSC(config-log)#
```

(1) Configure a GSMTAP logging target recording to 192.168.2.3

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.

The GSMTAP logging target also has different implementation I/O modes, which can be configured during the VTY "log gmstap" VTY command:

nonblocking-io
: Use non-blocking, synchronous I/O. This is the default mode. It will set the GSMTAP source socket as non-blocking, and attempt synchronous write to the UDP socket, discarding a message if the UDP socket's send buffer is full during write.

blocking-io
: Use blocking, synchronous I/O. It will use the GSMTAP source socket in blocking mode, and attempt synchronous write to the UDP socket, blocking the entire thread if the UDP socket's send buffer is full during write. This I/O mode should not be used in any osmocom program driven by an event loop (which includes any program using a VTY), since it may block the thread for an unspecified (potentially long or even infinite) amount of time and hence prevent the event loop to run and process events. This I/O mode should only be used under specific circumstances, like debugging a crash, in which case it's interesting to get the logging output to the UDP socket and hence recorded before the program crashes.

wq
: Workqueue mode: Use non-blocking, asynchronous I/O. It will set the GSMTAP source socket as non-blocking, and attempt asynchronous write to the UDP socket by means of a work queue driven by the process poll event loop, delaying writing to the UDP socket until there's enough free space in its send buffer. Since the workqueue has a maximum size, messages will be discarded similar to *nonblocking-io* once the UDP socket's send buffer **and** the GSMTAP log target workqueue are full. This I/O mode provides some extra buffering space in the userspace workqueue, at the expense of extra overhead and delay to transmit messages asynchronously waiting for POLLOUT event from the UDP socket.

In any of the I/O modes above, the UDP socket send buffer size of the GSMTAP log target influences where messages may be dropped (*nonblocking-io*|*wq*) or the process blocked (*blocking-io*) whenever a high number of messages or test are transmitted in a short time. For that reason, the GSMTAP log target will attempt to set the `SO_SNDBUF` sockopt of the UDP socket to 4MB. In Linux, the `SO_SNDBUF` value being set on the socket will be trimmed by the kernel to a maximum allowed by sysctl `net.core.wmem_max`. Hence, if you want to be on a safer side minimizing dropping messages or blocking the process (depending on the I/O mode set), make sure sysctl `net.core.wmem_max` on your system is set to `4194304` (4MB) or more.

Note
Linux Kernel used to have a `net.core.wmem_max` of `212992`(208KB) until recently (2025, a6d4f25888b83b8300aef28d9ee22765c1cc9b34), where it was increased to `4194304` (4MB) .

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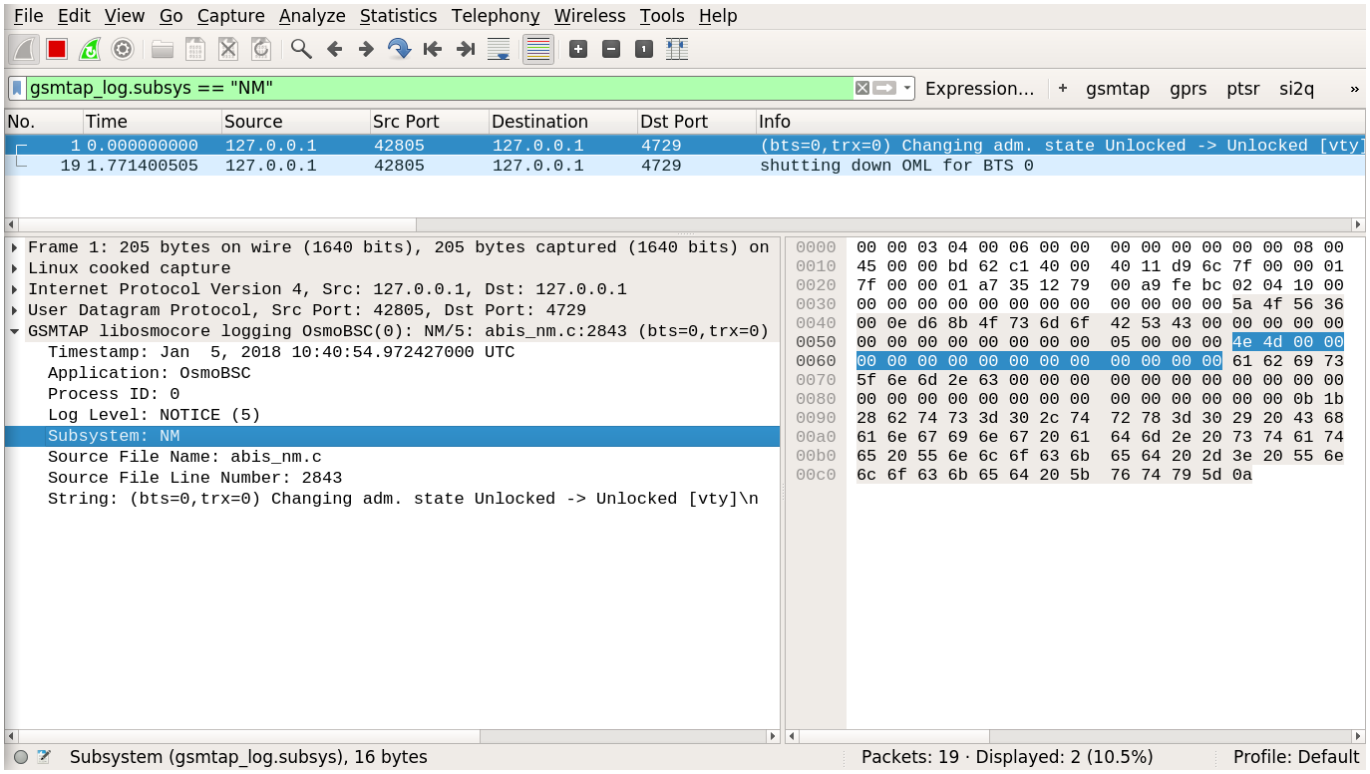

Figure 4: Wireshark with logs delivered over GSMTAP

Note

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

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 ❶
OsmoBSC(config-log)#
```

❶ Configure a file logging target writing to /path/to/my/file

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`.

The file logging target will by default use a synchronous non-blocking I/O write. If writing cannot be performed synchronously (would block), the message is stored in a workqueue where asynchronous write (driven by poll event loop) will be performed at a later stage. The file logging target can be configured during the VTY `log file` VTY command to perform blocking I/O with the `blocking-io` parameter. This I/O mode should not be used in any osmocom program driven by an event loop (which includes any program using a VTY), since it may block the thread for an unspecified (potentially long or even infinite) amount of time and hence prevent the event loop to run and process events. This I/O mode should only be used under specific circumstances, like debugging a crash, in which case it's interesting to get the logging output to the UDP socket and hence recorded before the program crashes.

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`.

Tip
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.

Note
Typical syslog implementations (such as glibc's one) write to *AF_UNIX* socket in `/dev/log` in a synchronous blocking I/O fashion, which means transmitting a big amount of messages or text over it in a short amount of time (before syslogd has time to read it) could potentially block the osmocom program's thread issuing the logging. It is hence advised avoiding use of this log target to log notable amounts of information in any osmocom program driven by an event loop (which includes any program using a VTY), since it may block the thread for an unspecified (potentially long or even infinite) amount of time and hence prevent the event loop to run and process events.

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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.

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

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

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

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

You can configure systemd based logging in two ways:

Example: systemd-journal target with offloaded rendering

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

❶ `raw` logging handler, rendering offloaded to systemd.

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

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

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

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

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

Example: systemd-journal target with libosmocore based rendering

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

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❶ Generic logging handler, rendering is done by libosmocore.

❷ Disable timestamping, systemd will timestamp every message anyway.

❸ 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*.

Note
systemd-journal logging target uses libsystemd, which implements *Native Journal Protocol* (*AF_UNIX _DATAGRAM* socket). That socket is internally configured in synchronous blocking I/O mode, which means transmitting a big amount of messages or text over it in a short amount of time (before systemd-journald has time to read it) could potentially block the osmocom program's thread issuing the logging. libsystemd currently sets the *AF_UNIX* socket `SO_SNDBUF` to 8MB. In Linux, the `SO_SNDBUF` value being set on the socket will be trimmed by the kernel to a maximum allowed by sysctl `net.core.wmem_max`. Hence, if you want to be on a safer side minimizing dropping messages or blocking the process (depending on the I/O mode set), make sure sysctl `net.core.wmem_max` on your system is set to `8388608` (8MB) or more. Besides, the kernel limits the amount of messages queued in *AF_UNIX* sockets to value set in sysctl `net.unix.max_dgram_qlen`, so you may also want to increase that one to be on the safe side if planning to log with a high frequency.

Note
Linux Kernel used to have a `net.core.wmem_max` of `212992`(208KB) until recently (2025, a6d4f25888b83b8300aef28d9ee22765c1cc9b34), where it was increased to `4194304` (4MB) .

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)#
```

The stderr logging target can be configured during the VTY `log stderr` VTY command to perform blocking I/O with the `blocking-io` parameter. See Section 7.5.4 for more information.

8 Configuring OsmoMGW

A basic configation of OsmoMGW mainly consists of specifying the IP address and port on which to listen to MGCP commands, but changing the port range at which the RTP streams terminate as well as limiting operation to a single call agent can be done as well as changing the number of endpoints.

8.1 Configuring MGCP

By default OsmoMGW listens for MGCP on port 2427 on any IP address. If a call agent address is configured then OsmoMGW will only answer MGCP commands from that IP port 2727, otherwise all sources are handled. A domain can be specified

Example: MGCP configuration

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```
OsmoMGW(config-mgcp)# bind ip 127.0.0.1
OsmoMGW(config-mgcp)# bind port 2427
OsmoMGW(config-mgcp)# call-agent ip 127.0.0.1
OsmoMGW(config-mgcp)# domain mgw-bsc
OsmoMGW(config-mgcp)# local ip 127.0.0.1
```

8.2 Configuring the trunk

The first trunk is considered a virtual trunk in OsmoMGW. All endpoints of type "rtpbridge" are routed here. The virtual trunk is configured in the config-mgcp context.

All other trunks are configured in the config-mgcp-trunk context, but the commands used are identical. Right now trunks are considered only for "ds/e1" type endpoints.

Example: MGCP trunk configuration

```
OsmoMGW(config-mgcp)# number endpoints 63 ❶
OsmoMGW(config-mgcp)# rtp bind-ip 10.0.0.1 ❷
OsmoMGW(config-mgcp)# rtp port-range 12000-14000 ❸
```

❶ Maximum number of endpoints that can be allocated at once

❷ Use this IP when binding RTP endpoints

❸ Use ports in this range when binding RTP endpoints

There are some options to tweak how RTP forwarding behaves in OsmoMGW:

Example: MGCP trunk rtp options

```
OsmoMGW(config-mgcp)# rtp keep-alive 30 ❶
OsmoMGW(config-mgcp)# rtp-patch ssrc ❷
OsmoMGW(config-mgcp)# rtp-patch timestamp ❸
```

❶ Send dummy UDP packets periodically to RTP destination

❷ Hide SSRC changes

❸ Ensure RTP timestamp is aligned with frame duration

Note
Changes to trunks that affect resource allocation, such as newly created trunks or a change of the number of available endpoints, require a full restart of osmo-mgw!

8.3 E1 trunk considerations

While the RTP bridge trunks are natively based on IP no special considerations are required during setup. E1 trunks are mapped on a physical E1 line, which has to be configured as shown below.

Example: E1 line setup

```
OsmoMGW(config-e1_input)# e1_line 0 driver dahdi ❶
OsmoMGW(config-e1_input)# e1_line 0 port 2 ❷
```

❶ Name of the libosmo-abis driver implementation ("dahdi")

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❷ Port number of the physical E1 port to use (2)

In osmo-mgw the e1_input node is used to configure the physical E1 line. The line number will be used internally to identify the configured E1 line. The port number is the physical E1 connector (sometimes called *span*) at the E1 hardware. Per trunk an individual E1 line will be needed. Beware that the E1 driver may also need configuration settings that are not discussed here.

Example: E1 trunk setup

```
OsmoMGW(config-mgcp)# trunk 0 ❶
OsmoMGW(config-mgcp-trunk)# line 0 ❷
```

❶ Creation of a trunk (0)

❷ Reference to the E1 line to use (0)

The E1 trunk is created along with a number, typically starting at 0, but if required any number from 0-64 is allowed. The E1 trunk configuration concerning the IP related aspects is nearly identical to the configuration of the virtual trunk. However, it is important that the user assigns one of the E1 line numbers that were configured under the e1_input node.

Note
The endpoint name that is used on MGCP level will include the trunk number, not the E1 line number. For simplicity (and compatibility with OsmoBSC) it is recommended to use equal numbers for trunk and E1 line. However, if required any E1 line can be mapped flexible on any trunk as long as the mapping is bijective.

Example: A typical configuration with one E1 trunk

```
e1_input
 e1_line 0 driver dahdi
 e1_line 0 port 2
mgcp
 bind ip 127.0.0.1
 rtp net-range 6000 6011
 rtp net-bind-ip 192.168.100.130
 rtp ip-probing
 rtp ip-dscp 46
 no rtp keep-alive
 bind port 2428
 number endpoints 30
 loop 0
 force-realloc 1
 osmux off
 rtp-patch rfc5993hr
 trunk 0
  rtp keep-alive once
  no rtp keep-alive
  line 0
```

Note
One E1 trunk always covers a whole E1 line. All subslots (I.640) will be mapped to individual MGCP endpoints. As long as the endpoints remain unused the underlying E1 timeslot is not used.

Note
The E1 trunk implementation also works with T1 lines, however since T1 has 24 instead of 31 usable timeslots only the endpoints that fall into that 1-24 timeslot range will be useable.

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9 MGCP Endpoints

MGCP organizes the switching resources in so called endpoints. Each endpoint is referenced by its unique identifier. While RFC 3435 specifies a naming scheme, the actual identifier naming is subject to the implementation and configuration.

9.1 RTP proxy / RTP bridge endpoints

OsmoMGW implements a freely configurable number of `rtpbridge` endpoints. Those endpoints are able to host two connections at a time to model the functionality of a tandem switch.

RTP bridge endpoint identifiers are referenced by the string `rtpbridge/`, a hexadecimal number without leading zeros and a domain name (configurable).

```
rtpbridge/<number>@<domain>
```

Example: List of virtual endpoints

```
rtpbridge/1@mgw
rtpbridge/2@mgw
rtpbridge/3@mgw
rtpbridge/4@mgw
rtpbridge/5@mgw
rtpbridge/6@mgw
rtpbridge/7@mgw
rtpbridge/8@mgw
rtpbridge/9@mgw
rtpbridge/a@mgw
rtpbridge/b@mgw
rtpbridge/c@mgw
rtpbridge/d@mgw
rtpbridge/e@mgw
rtpbridge/f@mgw
rtpbridge/10@mgw
```

9.2 E1/T1 endpoints

OsmoMGW supports E1 subslot multiplexing as specified by I.460. All possible subslot combinations are mapped on individual endpoints. The endpoint names are prefixed with `ds/e1-` followed by the trunk number and the E1 timeslot. The subslot is defined by a bit rate and a bit offset.

```
ds/e1-<trunk>/s-<timeslot>/su<bitrate>-<bitoffset>@<domain>
```

Example: List of endpoints on E1 trunk 0 at E1 timeslot 2

```
ds/e1-0/s-2/su64-0@mgw
ds/e1-0/s-2/su32-0@mgw
ds/e1-0/s-2/su32-4@mgw
ds/e1-0/s-2/su16-0@mgw
ds/e1-0/s-2/su16-2@mgw
ds/e1-0/s-2/su16-4@mgw
ds/e1-0/s-2/su16-6@mgw
ds/e1-0/s-2/su8-0@mgw
ds/e1-0/s-2/su8-1@mgw
ds/e1-0/s-2/su8-2@mgw
ds/e1-0/s-2/su8-3@mgw
ds/e1-0/s-2/su8-4@mgw
ds/e1-0/s-2/su8-5@mgw
ds/e1-0/s-2/su8-6@mgw
ds/e1-0/s-2/su8-7@mgw
```

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When creating connections on endpoints that reside in one E1 timeslot the call agent must make sure that no overlapping endpoints are used. It is for example not possible to use `ds/e1-0/s-2/su16-2@mgw` and `ds/e1-0/s-2/su8-3@mgw` at the same time because they overlap.

Table 2: Subslot overlapping

Bit offset	Subslots			
0	8k	16k	32k	64k
1	8k			
2	8k	16k		
3	8k			
4	8k	16k	32k	
5	8k			
6	8k	16k		
7	8k			

Note
The current implementation (December 2020) only implements TRAU frame encoding/decoding for 16K and 8K subslots. Endpoints with other bitrates are not yet useable.

Note
the VTY command "show mgcp" can be used to get a list of all available endpoints (including identifiers)

9.3 The `null` endpoint

OsmoMGW offers a special `null@<domain>` endpoint which can be audited at all times. This is useful for MGCP clients who wish to submit requests to OsmoMGW periodically to find out whether it is still reachable and in a working state.

10 MGCP Extensions

The MGCP protocol is extendable. The following non-standard extensions are understood by OsmoMGW.

10.1 `X-Osmo-IGN`

`X-Osmo-IGN` indicates to OsmoMGW that specific items of an endpoint should be ignored, so that it is lenient on mismatching values that would normally indicate collisions or configuration errors.

10.1.1 `X-Osmo-IGN` Format

The value part of `X-Osmo-IGN` must be one or more items separated by one or more spaces. Each item consists of one or more non-whitespace characters.

Example: X-Osmo-IGN format with three ficticious items "X", "abc" and "123".

```
X-Osmo-IGN: X abc 123
```

`X-Osmo-IGN` must be issued in the MGCP header section (typically as its last item), before the SDP section starts.

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10.1.2 Supported X-Osmo-IGN Items

Currently, the following X-Osmo-IGN items are supported:

- C: ignore CallID mismatches, i.e. differing "C" values between connections on the same endpoint.

Note: X-Osmo-IGN does not support ignoring mismatches on the domain part of an endpoint name, e.g. ignoring a mismatch on "example.com" in rtpbridge/123abc@example.com. Instead, you may globally configure OsmoMGW with mgcp / domain * to permit all domain parts.

10.1.2.1 X-Osmo-IGN: C

By default, OsmoMGW verifies that all CallIDs ("C" values) match for all connections on any one given endpoint. To ignore CallID mismatches, pass a C in the X-Osmo-IGN header, for the first or the second CRCX on an endpoint. When the X-Osmo-IGN: C is sent for any one CRCX on an endpoint, CallID mismatches will be ignored for that and all subsequent messages for that endpoint. Hence this header only needs to be included once per endpoint, in any CRCX message that precedes or coincides with a CallID mismatch.

This is particularly useful for a BSC that is connected to an A/SCCPlite MSC, where the BSC and MSC each are expected to configure their respective own connection on a shared endpoint. For A/SCCPlite, it is impossible for the BSC to know the CallID that the MSC will use, so CallID mismatches are inevitable. See also OsmoBSC, which will by default pass the X-Osmo-IGN: C header for endpoints associated with an A/SCCPlite MSC.

Example: CRCX message that instructs OsmoMGW to ignore CallID mismatches

```
CRCX 2 rtpbridge/123abc@mgw MGCP 1.0
M: recvonly
C: 2
L: p:20
X-Osmo-IGN: C

v=0
c=IN IP4 123.12.12.123
m=audio 5904 RTP/AVP 97
a=rtpmap:97 GSM-EFR/8000
a=ptime:40
```

10.2 X-Osmux

See Section 11.6

10.3 Non-standard SDP codec parameters

CRCX command message normally includes an SDP block that specifies the RTP address of the connecting peer and the list of codecs accepted by that entity. Codec specifications may include optional parameters given via a=fmtp lines; one well-known parameter is octet-align, defined for AMR and AMR-WB codecs.

In addition to standard (RFC-defined) codec parameters (of which the just-mentioned octet-align parameter is the only one implemented so far), OsmoMGW also understands some non-standard (Osmocom-private) codec parameters as listed below. These Osmocom-private codec parameters are meaningful only in the context of OsmoBSC driving an E1 Abis MGW, which may be either OsmoMGW or a specialized third-party replacement.

The MGCP extension described in this section is meaningful only for E1 endpoints - it has absolutely no effect on rtpbridge endpoints!

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10.3.1 `tw-ts-001` parameter for FR and EFR codecs

GSM Full Rate codec is known in SDP as `GSM`; GSM Enhanced Full Rate codec is known in SDP as `GSM-EFR`. When either codec is to be transported in RTP, there is a choice between two different payload formats: RFC 3551 or TW-TS-001. RFC 3551 is the standard in non-GSM Internet applications, and it is the format specified in later 3GPP releases for IP-based transport of compressed speech - however, it exhibits functional regressions compared to the original TRAU-UL frame format of GSM 08.60. TW-TS-001 is an enhanced alternative payload format for the same codecs that restores the original functionality and semantics of TRAU-UL frames.

In the context of CRCX or MDCX command messages from OsmoBSC to an E1 Abis MGW, `tw-ts-001` codec parameter (attached to either `GSM` or `GSM-EFR` codec) instructs the MGW whether or not it should emit the extended payload format of TW-TS-001 for GSM uplink traffic converted to RTP. In the absence of this parameter, IETF-standard and 3GPP-standard RFC 3551 format is emitted; if TW-TS-001 output is desired, please specify `tw-ts-001=1` on the appropriate `a=fmtp` line.

Example: CRCX message requesting EFR codec with TW-TS-001 extensions

```
CRCX 2 ds/e1-0/s-2/su16-2@mgw MGCP 1.0
M: recvonly
C: 2
L: p:20

v=0
c=IN IP4 123.12.12.123
m=audio 1234 RTP/AVP 110
a=rtpmap:110 GSM-EFR/8000/1
a=fmtp:110 tw-ts-001=1
```

10.3.2 `tw-ts-002` parameter for HR codec

GSM Half Rate codec is known in SDP as `GSM-HR-08`. The same dichotomy that exists between RFC 3551 and TW-TS-001 RTP payload formats for FR and EFR codecs also exists for HR codec, except that the two opposing alternatives are now RFC 5993 and TW-TS-002.

In the context of CRCX or MDCX command messages from OsmoBSC to an E1 Abis MGW, `tw-ts-002` codec parameter (attached to `GSM-HR-08` codec) instructs the MGW whether or not it should emit the extended payload format of TW-TS-002 for GSM uplink traffic converted to RTP. In the absence of this parameter, IETF-standard and 3GPP-standard RFC 5993 format is emitted; if TW-TS-002 output is desired, please specify `tw-ts-002=1` on the appropriate `a=fmtp` line.

Example: CRCX message requesting HR codec with TW-TS-002 extensions

```
CRCX 2 ds/e1-0/s-2/su8-2@mgw MGCP 1.0
M: recvonly
C: 2
L: p:20

v=0
c=IN IP4 123.12.12.123
m=audio 1234 RTP/AVP 111
a=rtpmap:111 GSM-HR-08/8000/1
a=fmtp:111 tw-ts-002=1
```

11 Osmux

`Osmux` is a protocol aimed at multiplexing and transmitting voice and signalling traffic from multiple sources in order to reduce the overall bandwidth consumption. This feature becomes specially meaningful in case of satellite based GSM systems, where the transmission cost on the back-haul is relatively expensive. In such environment, even seemingly small protocol optimizations, eg. message batching and trunking, can result in significant cost reduction.

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Full reference document for the osmux protocol can be found here: https://ftp.osmocom.org/docs/latest/osmux-reference.pdf

In Osmocom satellite based GSM networks, the satellite link is envisioned to be in between the BSS and the core network, that is, between the BSC and the MSC (or BSC-NAT). Hence, Osmocom components can make use of `Osmux` protocol to multiplex payload audio streams from call legs between OsmoBSC and OsmoMSC (or OsmoBSCNAT). The MGW attached those components need of course also be aware of `Osmux` existence in order to properly set up the audio data plane.

Under some specific circumstances, the operator may decide to set up the network with a bandwidth-limited (e.g. satellite) link between BTS and BSC. Hence, use of the `Osmux` protocol is also possible between an Osmux capable BTS (like OsmoBTS) and OsmoBSC (and its co-located MGW).

11.1 Osmux and NAT

It is quite usual for satellite based links to use NATs, which means any or both of the two components at each side of the satellite link (BSC and MSC/BSC-NAT) may end up being behind a NAT and being unable to provide the real public address to its peer on the other side of the satellite.

As a result, upon call parameter negotiation (RTP/Osmux IP address and port), those parameters won't be entirely useful and some specific logic needs to be introduced into the network components to circumvent the NAT under those cases.

For instance, if the BSC and its co-located MGW (BSC/MGW from now on) is under a NAT, it may end up providing its private address and port as RTP/Osmux parameters to the MSC/MGW through GSM protocols, but MSC will fail to send any message to that tuple because of the NAT or routing issues (due to IP address being a private address). In that scenario, MSC/MGW needs to be aware that there's a NAT and wait until an RTP/Osmux message arrives from the BSC/MGW host. It then can, from that message source IP address and port (and CID in case of Osmux), discover the real public IP address and port of the peer (BSC/MGW). From that point on, the BSC/MGW punched a hole in the NAT (its connection table is updated) and MSC/MGW is able to send data back to it on that connection.

In order to make use of the features above, OsmoMGW must be made aware explicitly through VTY configuration that its peers are located behind a NAT. This is done through the `osmux peer-behind-nat (on|off)` VTY commands.

If OsmoMGW itself is behind a NAT, it must use the VTY config `rtp keep-alive` (used for both RTP and Osmux) to at least the value `once`, in order for it to punch the hole in its NAT so that its peer can know where to send packets back to it.

Another characteristic of NATs is that they tend to drop connections from their connection tables after some inactivity time, meaning a peer may receive notice about the other end not being available while it actually is. This means the GSM network needs to be configured in a way to ensure inactivity periods are short enough that this cannot occur.

Hence, if OsmoMGW is behind a NAT, it is actually desirable to have the VTY config `rtp keep-alive` configured with the `<1-120>` value in order to force transmission of dummy packets ever few seconds.

Osmux implementations such as OsmoMGW also come with the `osmux dummy` VTY command to enable sending dummy AMR payloads to the peer even if no real data was received (for instance if DTX is used). This is useful under some specific satellite links which were proven to work unreliably if the total throughput in use over the link changes over time. This way throughput resources are kept pre-allocated until they are needed again (audio is received again).

11.2 CID allocation

Each peer (BSC/MGW and MSC/MGW) allocates its own *local CID*, and receives from its peer a *remote CID* (aka the peer's *local CID*) through the used GSM protocol. This *remote CID* is then used to send Osmux frames to that peer.

```
BSC/MGW(localCID=Y,remoteCID=?)<-X--MSC/MGW(localCID=X,remoteCID=?)
BSC/MGW(localCID=Y,remoteCID=X)--Y->MSC/MGW(localCID=X,remoteCID=Y)
```

This way each peer is responsible for allocating and managing their own local address (CID) space. This is basically the same that happens with regular IP address and port in the RTP case (and those also apply when Osmux is used, but an extra identifier, the CID, is allocated).

In an ideal scenario, without NAT, each BSC/MGW would have a public, differentiated and unique IP and port set tuple, And MSC/MGW should be able to identify messages coming from them by easily matching source IP address, port (and CID in Osmux case) against the parameters negotiated during call set up.

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In this kind of scenario, MSC/MGW could easily open and manage one Osmux socket per BSC (based on SDP IPaddr and port parameters), with same `<localIPaddr, localPort>` tuple, allowing for 256 Osmux CIDs per BSC and hence call legs per BSC. Each of the peers could actually have more than one Osmux socket towards the other peer, by using a pool of ports or IP addresses, so there's really not limit if required as long as there's a way to infer the initially negotiated `<srcIP, srcPort, dstIP, dstPort, remoteCID>` tuple from the received audio packets.

However, due to some constrains from in between NATs explained in section above, BSC/MGW IP address and port are not a priory known, and could change between different connections coming from it. As a result, it is difficult to infer the entire tuple, so for now MGW needs to allocate its Osmux *local CID* in a clever way, in order to be able to identify the full tuple from it.

Hence, currently OsmoMGW CID allocation implementation shares CID between all connections, which means it can only handle up to 256 concurrent Osmux connections (call legs).

Future work in OsmoMGW (OS#4092) plans to use a set of local ports for Osmux sockets instead of only 1 currently used. This way local ports can be matched against specific `<remoteIP, remotePort>` tuples and have an entire 256 Osmux CID space per `<remoteIP, remotePort>` (aka per peer).

11.3 3GPP AoIP network setup with Osmux

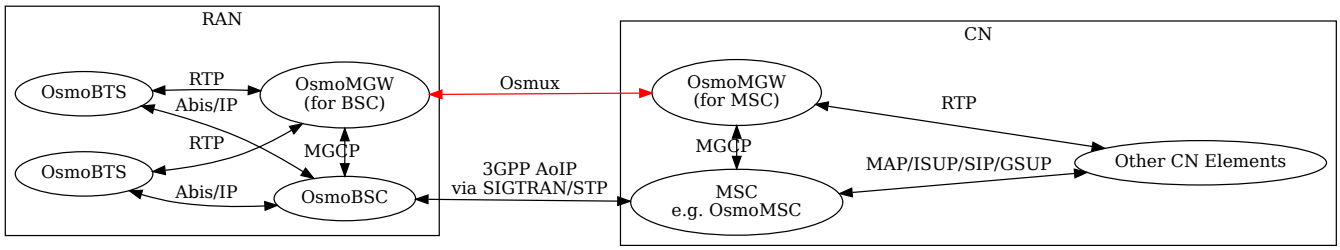

Figure 5: Sample node diagram of a 3GPP AoIP network with Osmux enabled

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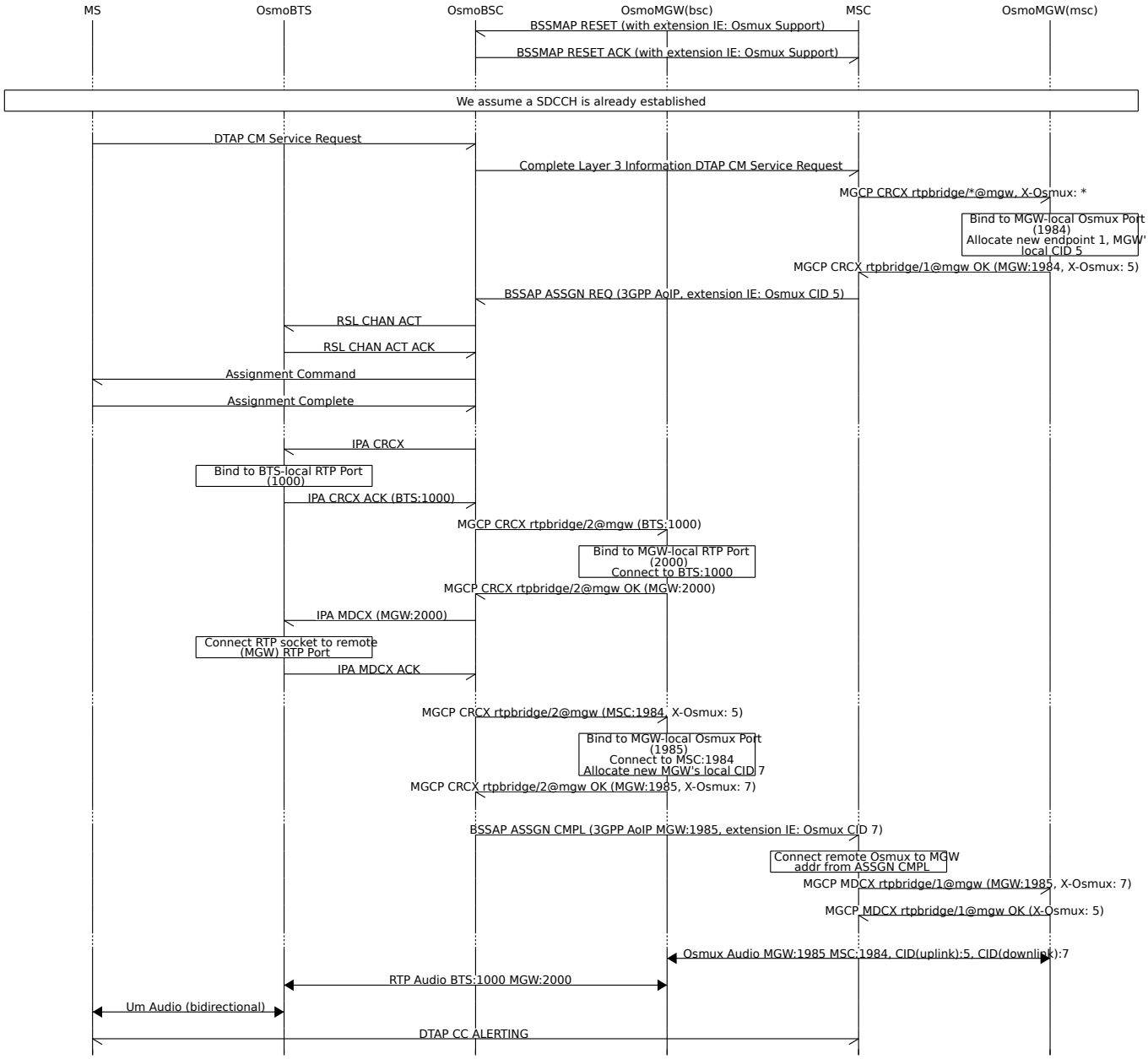

Figure 6: MO-call with Osmux enable on 3GPP AoIP

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11.4 SCCPLite network setup with Osmux

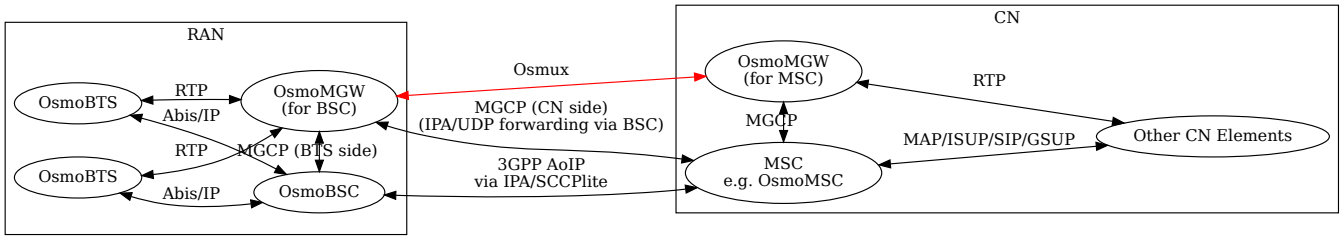

Figure 7: Sample node diagram of a 3GPP AoIP using A/IP with IPA/SCCPlite network with Osmux enabled

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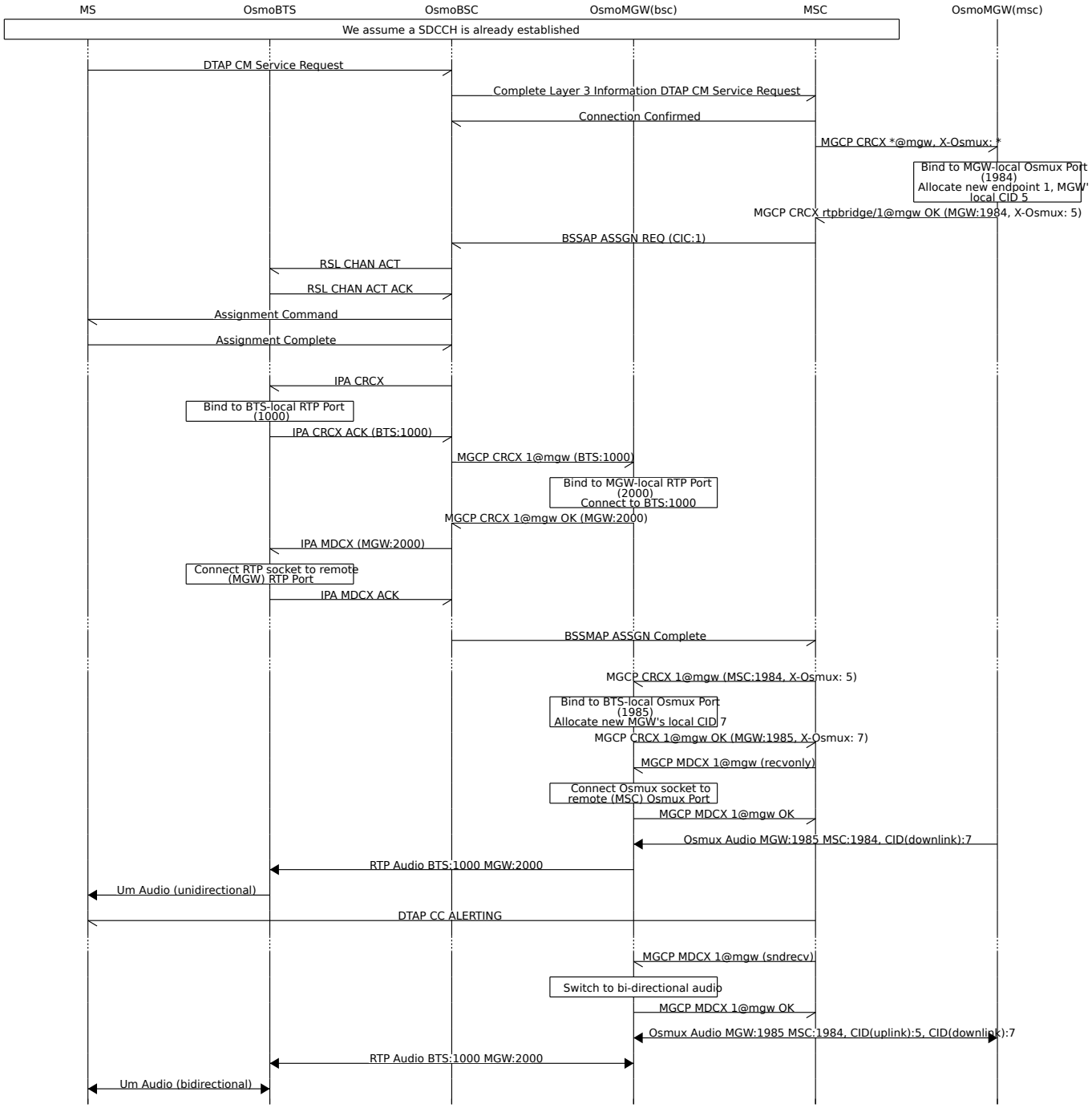

Figure 8: MO-call with Osmux enable on 3GPP AoIP using A/IP with IPA/SCCPlite

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11.5 SCCPLite network setup with Osmux + BSC-NAT

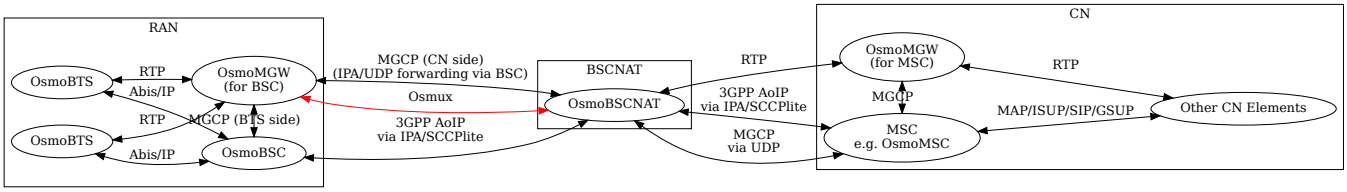

Figure 9: Sample node diagram of a 3GPP AoIP using A/IP with IPA/SCCPlite network and BSC-NAT with Osmux enabled

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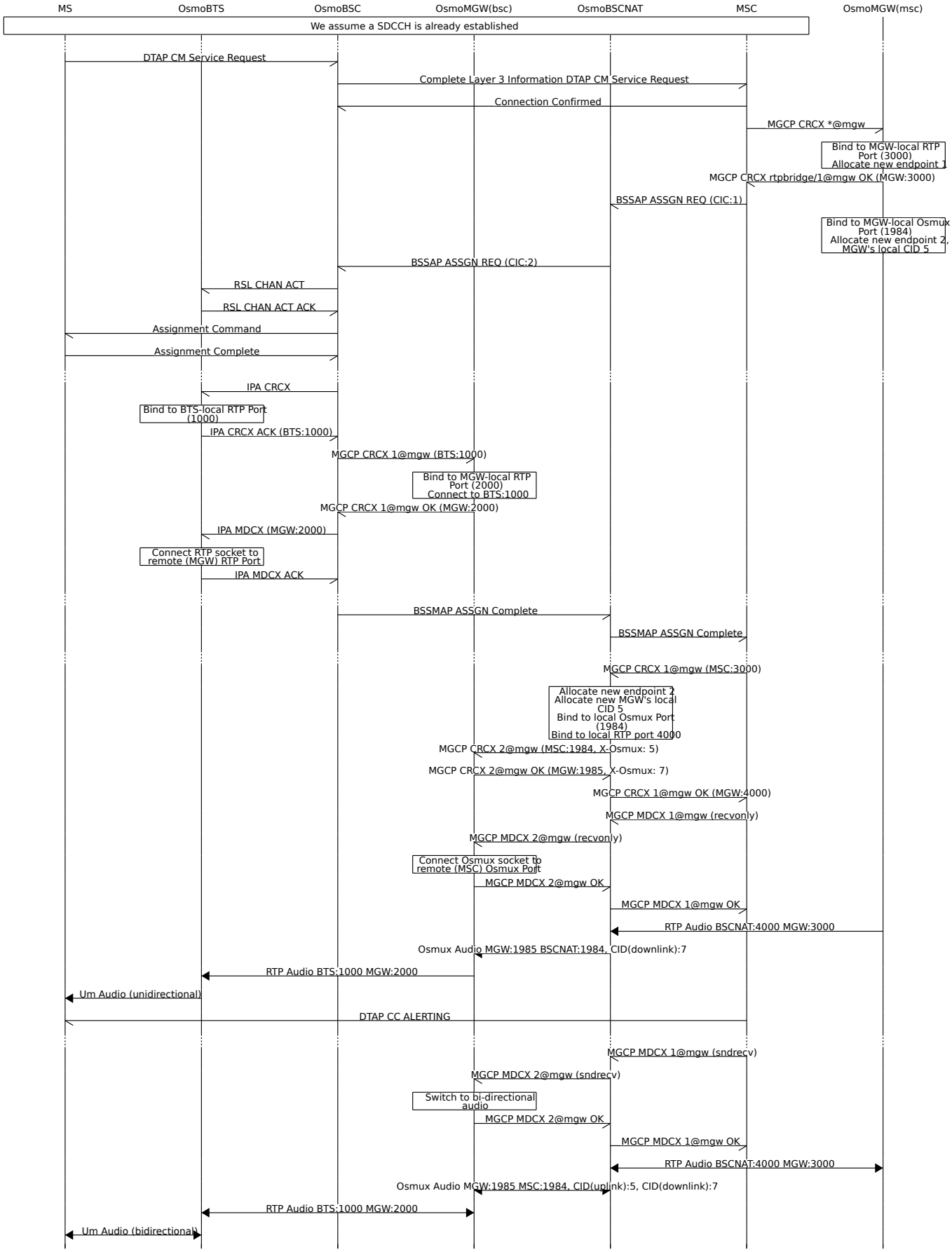

Figure 10: MO-call with Osmux enable on 3GPP AoIP using A/IP with IPA/SCCPlite with a BSC-NAT between BSC and MSC

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11.6 Osmux and MGCP

X-Osmux indicates to OsmoMGW that a given connection of an rtpbridge endpoint has to be configured in order to handle Osmux frames instead of RTP messages on the data plane.

11.6.1 X-Osmux Format

The value part of X-Osmux must be one integer in range [0..255], or alternatively only on request messages, an asterisk (*) if the value is not yet known.

X-Osmux must be issued in the MGCP header section (typically as its last item), before the SDP section starts.

X-Osmux can be included inside CRCX and MDCX request messages, as well as their respective response messages.

In request messages, the value part of X-Osmux specifies the CID to be used by OsmoMGW to *send* Osmux frames to the remote peer for that connection, also known as the MGW's *remote CID* or the peer's *local CID*.

In response messages, the value part of X-Osmux specifies the CID where OsmoMGW expect to *receive* Osmux frames from the remote peer for that connection, also known as the MGW's *local CID* or the peer's *remote CID*.

Example: X-Osmux format with a known CID 3.

```
X-Osmux: 3
```

Example: X-Osmux format with a wildcard (not yet known) CID.

```
X-Osmux: *
```

11.6.2 X-Osmux Considerations

If the MGCP client is willing to use Osmux for a given connection, it shall specify so during CRCX time, and not later. If at CRCX time the MGCP client doesn't yet know the MGW's *remote CID*, it can use an astersik (*) and provide *remote CID* later within MDCX messages.

All subsequent MDCX messages sent towards an Osmux connection must contain the original MGW's *remote CID* sent during CRCX. The same way, all MDCX response shall contain the *local CID* sent during CRCX.

The other required connection address parameters, such as IP address, port, and codecs, are negotiated through MGCP and SDP as usual, but in this case the IP address and port specific the Osmux socket IP address and port to use, that together with the Osmux CID conform the entire tuple identifying a Osmux stream.

Since Osmux only supports AMR codec payloads, the SDP must specify use of AMR codec.

Example: CRCX message that instructs OsmoMGW to create an Osmux connection

```
CRCX 189 rtpbridge/1@mgw MGCP 1.0
C: 36
M: sendrecv
X-Osmux: 2

v=0
o=- 36 23 IN IP4 172.18.2.20
s=-
c=IN IP4 1.2.3.4
t=0 0
m=audio 2342 RTP/AVP 112
a=fmtp:112
a=rtpmap:112 AMR/8000/1
a=ptime:20
```

Example: response to CRCX containing the MGW's local CID

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```
200 189 OK
I: 07E41584
X-Osmux: 2
Z: rtpbridge/1@mgw

v=0
o=- foo 21 IN IP4 172.18.1.20
s=-
c=IN IP4 172.18.1.20
t=0 0
m=audio 11002 RTP/AVP 112
a=rtpmap:112 AMR/8000
a=ptime:20
```

11.6.3 `X-Osmux` Support

`X-Osmux` is known to be supported by OsmoMGW on the MGCP server side, and by OsmoBSC as well as OsmoMSC on the MGCP client side (through libosmo-mgcp-cli). No other programs supporting this feature are known or envisioned at the time of writing this document.

In OmoMGW, Osmux support is managed through VTY.

Example: Sample config file section with Osmux configuration

```
mgcp
 ...
 osmux on ❶
 osmux bind-ip 172.18.1.20 ❷
 osmux port 1984 ❸
 osmux batch-factor 4 ❹
 osmux dummy on ❺
```

❶ Allow clients to set allocate Osmux connections in `rtpbridge` endpoints, while still allowing RTP connections

❷ Bind the Osmux socket to the provided IP address

❸ Bind the Osmux socket to the provided UDP port

❹ Batch up to 4 RTP payloads of the same stream on each Osmux frame

❺ Periodically send Osmux dummy frames, useful to punch a hole in NATs and maintain connections opened.

11.7 Abis setup with Osmux

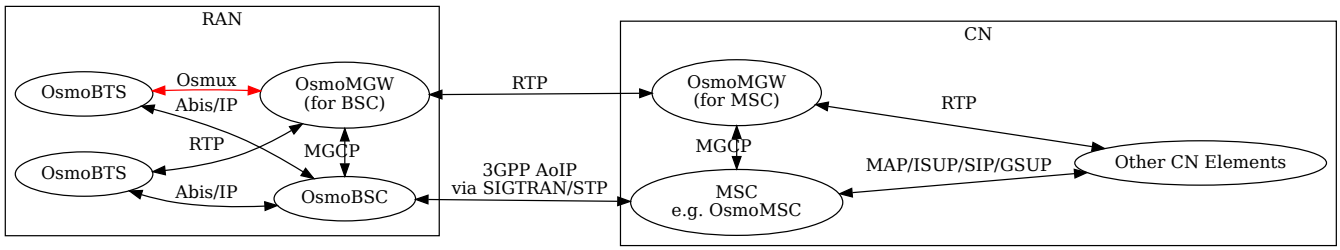

Figure 11: Sample node diagram of Osmux enabled in the Abis interface

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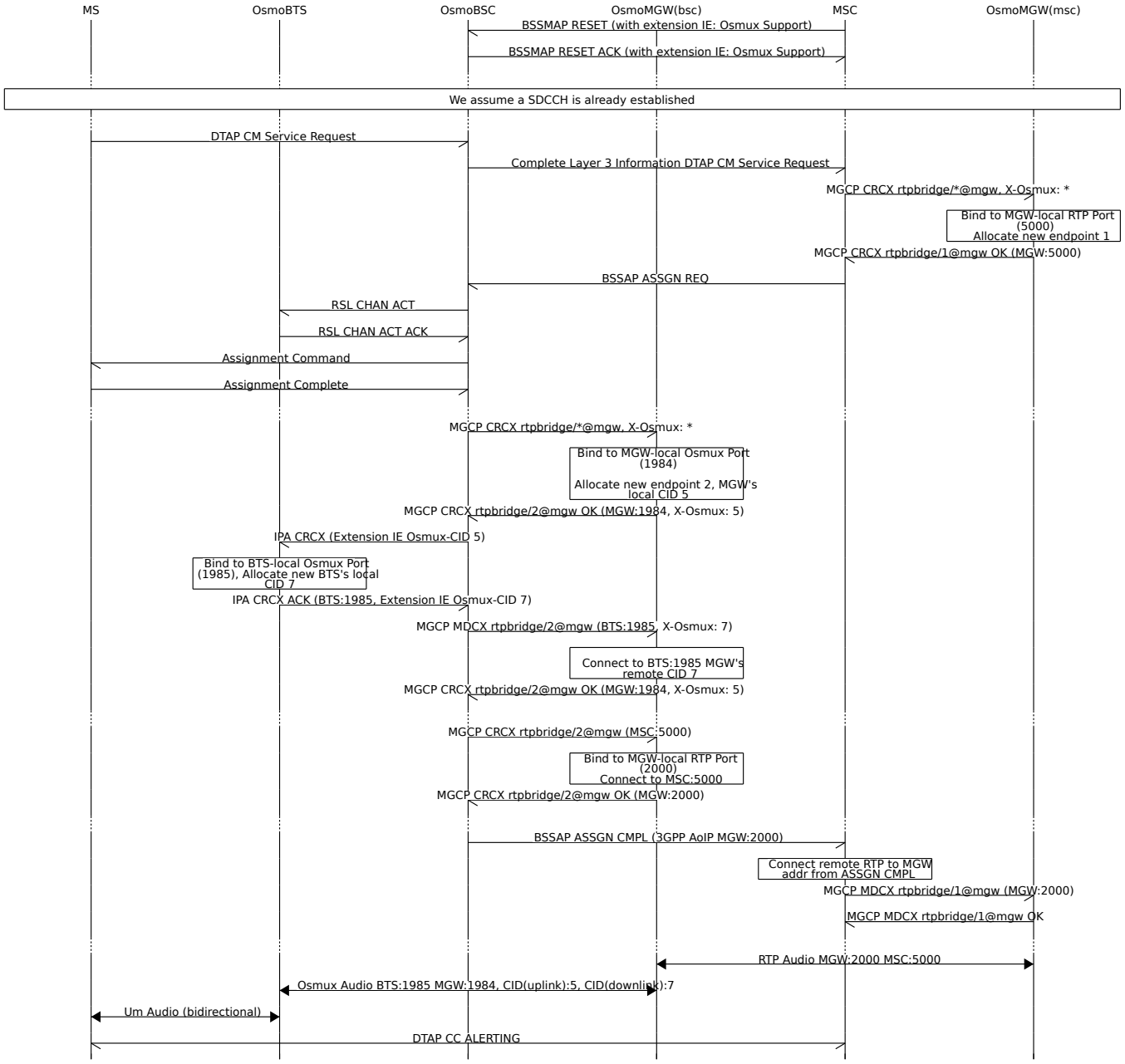

Figure 12: MO-call with Osmux enabled on Abis

12 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.

12.1 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

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[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.

12.2 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 3: Linux kernel default DSCP/TOS → priority mapping

TOS (binary)	DSCP (binary)	Priority (decimal)
xxx0000x	xxx000	0
xxx0001x	xxx000	0
xxx0010x	xxx001	0
xxx0011x	xxx001	0
xxx0100x	xxx010	2
xxx0101x	xxx010	2
xxx0110x	xxx011	2
xxx0111x	xxx011	2
xxx1000x	xxx100	6
xxx1001x	xxx100	6
xxx1010x	xxx101	6
xxx1011x	xxx101	6
xxx1100x	xxx110	4
xxx1101x	xxx110	4
xxx1110x	xxx111	4
xxx1111x	xxx111	4

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)

12.3 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.

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NOTE

This means that PCP functionality requires the use of IEEE 802.q 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

```
$ sudo cat /proc/net/vlan/eth0.9❶
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 ❷
 EGRESS priority mappings: ❸
```

❶ make sure to specify your specific VLAN interface name here instead of `eth0.9`

❷ ingress priority mappings (all PCP values mapped to priority 0)

❸ 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

```
$ sudo ip link set dev eth0.9❶ type vlan egress-qos-map 1:1 2:2 3:3 ❷
$ sudo cat /proc/net/vlan/eth0.9 ❸
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 ❹
```

❶ make sure to specify your specific VLAN interface name here instead of `eth0.9`

❷ command to define three new egress QoS maps

❸ command to re-display the current status

❹ three 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.

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12.4 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 → 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

12.4.1 Full example of QoS for osmo-mgw

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

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

Table 4: DSCP and PCP assignments for osmo-mgw Abis downlink traffic in this example

Traffic	DSCP	PCP
RTP	46	6

1. configure the osmo-mgw program to set the DSCP value
2. configure an egrees QoS map to map from priority to PCP

Example Step 1: add related VTY configuration to osmo-mgw.cfg

```
...
mgcp
 rtp ip-dscp 46
 rtp socket-priority 6
...
```

Example Step 2: egress QoS map to map from socket priority to PCP values

```
$ sudo ip link set dev eth0.9❶ type vlan egress-qos-map 0:0 5:5 6:6 7:7 ❷
```

❶ make sure to specify your specific VLAN interface name here instead of `eth0.9`.

❷ create a egress QoS map that maps the priority value 1:1 to the PCP. We also include the mapping 5:5 and 7:7 from the osmo-bsc example (see [userman-osmobsc]) here.

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.

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13 VTY Process and Thread management

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

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

13.1 Scheduling Policy

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

Example: Set process to use RR scheduler

```
cpu-sched
 policy rr 1 (1)
```

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

Note
Running a process under real time priority requires CAP_SYS_NICE capabilities. In order to avoid running the process as *root* user, you can either modify the binary permissions with `setcap "CAP_SYS_NICE+ep" /path/to/binary`, or allow the user running the program to set rtprio by adding a file */etc/security/limits.d/youruser_allow-rtprio.conf* with something like `youruser - rtprio 99`. See `man 7 sched` for more information on the topic.

13.2 CPU-Affinity Mask

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

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

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

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

```
cpu-sched
 cpu-affinity self 0x01 (1)
```

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

Or otherwise:

```
cpu-sched
 cpu-affinity all 0x01 (1)
```

(1) Allow all threads only on CPU 0

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

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

Example: Get osmo-trx Thread list information from VTY

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

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

Example: Set CPU-affinity from VTY telnet interface

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

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

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

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

Example: Set CPU-affinity from VTY config file

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

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

14 Glossary

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

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

3GPP
3rd Generation Partnership Project

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

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

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

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

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

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

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

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

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

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

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

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

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

BTS
Base Transceiver Station

BSC
Base Station Controller

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

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

BVCI
BSSGP Virtual Circuit Identifier

CBC
Cell Broadcast Centre; central entity of Cell Broadcast service

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

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CBS
Cell Broadcast Service

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

CC
Call Control; Part of the GSM Layer 3 Protocol

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

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

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

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

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

dB
deci-Bel; relative logarithmic unit

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

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

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

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

DSP
Digital Signal Processor

dvnixload
Tool to program UBL and the Bootloader on a sysmoBTS

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

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

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

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

ETSI
European Telecommunications Standardization Institute

FPGA
Field Programmable Gate Array; programmable digital logic hardware

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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

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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

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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

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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

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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])

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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])

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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 5: TCP/UDP port numbers

L4 Protocol	Port Number	Purpose	Software
UDP	1984	Osmux	osmo-mgw, osmo-bts
UDP	2427	MGCP GW	osmo-bsc_mgcp, osmo-mgw
TCP	2775	SMPP (SMS interface for external programs)	osmo-nitb
TCP	3002	A-bis/IP OML	osmo-bts, osmo-bsc, osmo-nitb
TCP	3003	A-bis/IP RSL	osmo-bts, osmo-bsc, osmo-nitb
TCP	4227	telnet (VTY)	osmo-pcap-client
TCP	4228	telnet (VTY)	osmo-pcap-server
TCP	4236	Control Interface	osmo-trx
TCP	4237	telnet (VTY)	osmo-trx
TCP	4238	Control Interface	osmo-bts
TCP	4239	telnet (VTY)	osmo-stp
TCP	4240	telnet (VTY)	osmo-pcu
TCP	4241	telnet (VTY)	osmo-bts
TCP	4242	telnet (VTY)	osmo-nitb, osmo-bsc, cellmgr-ng
TCP	4243	telnet (VTY)	osmo-bsc_mgcp, osmo-mgw
TCP	4244	telnet (VTY)	osmo-bsc_nat
TCP	4245	telnet (VTY)	osmo-sgsn
TCP	4246	telnet (VTY)	osmo-gbproxy
TCP	4247	telnet (VTY)	OsmocomBB
TCP	4249	Control Interface	osmo-nitb, osmo-bsc
TCP	4250	Control Interface	osmo-bsc_nat
TCP	4251	Control Interface	osmo-sgsn
TCP	4252	telnet (VTY)	sysmobts-mgr
TCP	4253	telnet (VTY)	osmo-gtphub
TCP	4254	telnet (VTY)	osmo-msc
TCP	4255	Control Interface	osmo-msc
TCP	4256	telnet (VTY)	osmo-sip-connector
TCP	4257	Control Interface	osmo-ggsn, ggsn (OpenGGSN)
TCP	4258	telnet (VTY)	osmo-hlr
TCP	4259	Control Interface	osmo-hlr
TCP	4260	telnet (VTY)	osmo-ggsn
TCP	4261	telnet (VTY)	osmo-hnbgw
TCP	4262	Control Interface	osmo-hnbgw
TCP	4263	Control Interface	osmo-gbproxy
TCP	4264	telnet (VTY)	osmo-cbc
TCP	4265	Control Interface	osmo-cbc

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Table 5: (continued)

L4 Protocol	Port Number	Purpose	Software
TCP	4266	D-GSM MS Lookup: mDNS serve	osmo-hlr
TCP	4267	Control Interface	osmo-mgw
TCP	4268	telnet (VTY)	osmo-uecups
SCTP	4268	UECUPS	osmo-uecups
TCP	4269	telnet (VTY)	osmo-e1d
TCP	4270	telnet (VTY)	osmo-isdntap
TCP	4271	telnet (VTY)	osmo-smlc
TCP	4272	Control Interface	osmo-smlc
TCP	4273	telnet (VTY)	osmo-hnodeb
TCP	4274	Control Interface	osmo-hnodeb
TCP	4275	telnet (VTY)	osmo-upf
TCP	4276	Control Interface	osmo-upf
TCP	4277	telnet (VTY)	osmo-pfcp-tool
TCP	4278	Control Interface	osmo-pfcp-tool
UDP	4729	GSMTAP	Almost every osmocom project
TCP	5000	A/IP	osmo-bsc, osmo-bsc_nat
UDP	23000	GPRS-NS over IP default port	osmo-pcu, osmo-sgsn, osmo-gbproxy
TCP	48049	BSC-CBC (CBSP) default port	osmo-bsc, osmo-cbc

B Bibliography / References

B.0.0.0.1 References

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

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

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

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

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

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

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

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

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

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

Copyright © 2018 sysmocom - s.f.m.c. GmbH

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Copyright © 2018 sysmocom - s.f.m.c. GmbH

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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