

sysmocom

sysmocom - s.f.m.c. GmbH



OSMOCOM

OsmoTRX User Manual

by Pau Espin Pedrol

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The AsciiDoc source code of this manual can be found at <http://git.osmocom.org/osmo-gsm-manuals/>

HISTORY

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1 Foreword

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

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

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

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

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

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

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

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

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

1.1 Acknowledgements

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

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

- Jan Luebbe, Stefan Schmidt, Daniel Willmann, Pablo Neira, Nico Golde, Kevin Redon, Ingo Albrecht, Alexander Huemer, Alexander Chemeris, Max Suraev, Tobias Engel, Jacob Erlbeck, Ivan Kluchnikov

May the source be with you!

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

1.2 Endorsements

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

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

2 Preface

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

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

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

2.1 FOSS lives by contribution!

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

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

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

We’re looking forward to receiving your contributions.

2.2 Osmocom and sysmocom

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

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

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

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

2.3 Corrections

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

2.4 Legal disclaimers

2.4.1 Spectrum License

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



Warning

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

2.4.2 Software License

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

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

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

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

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

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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, GSM protocols, correctly installing, configuring and optimizing your GSM network will be tough, irrespective whether you use products with Osmocom software or those of traditional telecom suppliers.

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

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

Some of the useful skills we recommend are:

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

3.2 Getting assistance

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

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

4 Overview

4.1 About OsmoTRX

OsmoTRX is a C/C++ language implementation of the GSM radio modem, originally developed as the *Transceiver* part of OpenBTS. This radio modem offers an interface based on top of UDP streams.

The OsmoBTS `bts_model` code for OsmoTRX is called `osmo-bts-trx`. It implements the UDP stream interface of OsmoTRX, so both parts can be used together to implement a complete GSM BTS based on general-purpose computing SDR.

As OsmoTRX is general-purpose software running on top of Linux, it is thus not tied to any specific physical hardware. At the time of this writing, OsmoTRX supports a variety of Lime Microsystems and Ettus USRP SDRs via the UHD driver, as well as the Fairwaves UmTRX and derived products.

OsmoTRX is not a complete GSM PHY but *just* the radio modem. This means that all of the Layer 1 functionality such as scheduling, convolutional coding, etc. is actually also implemented inside OsmoBTS. OsmoTRX is a software-defined radio transceiver that implements the Layer 1 physical layer of a BTS comprising the following 3GPP specifications:

- TS 05.01 "Physical layer on the radio path"
- TS 05.02 "Multiplexing and Multiple Access on the Radio Path"
- TS 05.04 "Modulation"
- TS 05.10 "Radio subsystem synchronization"

As such, the boundary between OsmoTRX and `osmo-bts-trx` is at a much lower interface, which is an internal interface of other more traditional GSM PHY implementations.

Besides OsmoTRX, there are also other implementations (both Free Software and proprietary) that implement the same UDP stream based radio modem interface.

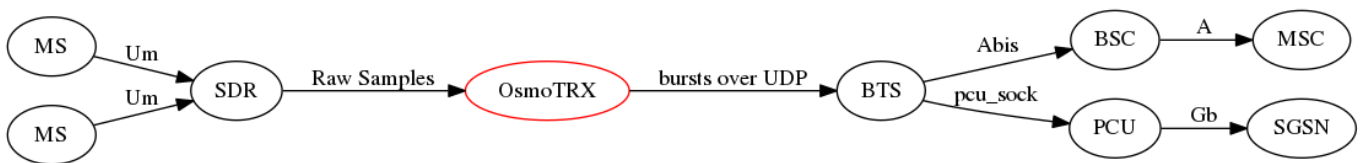


Figure 1: GSM network architecture with OsmoTRX and OsmoBTS

For more information see <https://osmocom.org/projects/osmotrx/wiki/OsmoTRX>

5 Running OsmoTRX

The OsmoTRX executable (`osmo-trx`) offers the following command-line options:

5.1 SYNOPSIS

```
osmo-trx [-h] [-C CONFIGFILE]
```

5.2 OPTIONS

-h

Print a short help message about the supported options

-C *CONFIGFILE*

Specify the file and path name of the configuration file to be used. If none is specified, use `osmo_trx.cfg` in the current working directory.

6 Osmocom Control Interface

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

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

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

6.1 Control Interface Protocol

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

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

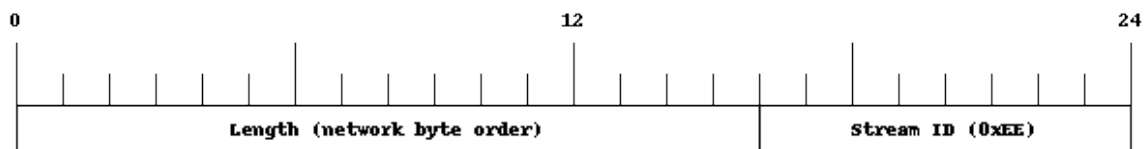


Figure 2: IPA header for control protocol

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

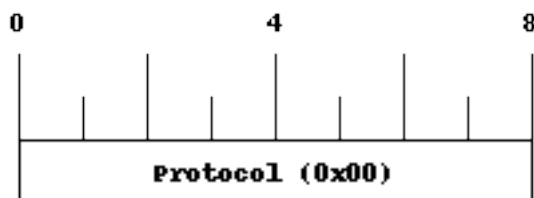


Figure 3: IPA extension header for control protocol

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

The fields specified below follow the following meaning:

<id>

A numeric identifier, uniquely identifying this particular operation. 0 is not allowed. It will be echoed back in any response to a particular request.

<var>

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

<val>

The value of the variable / field

<reason>

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

6.1.1 GET operation

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

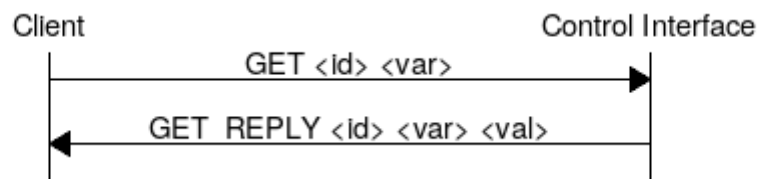


Figure 4: Control Interface GET operation (successful outcome)

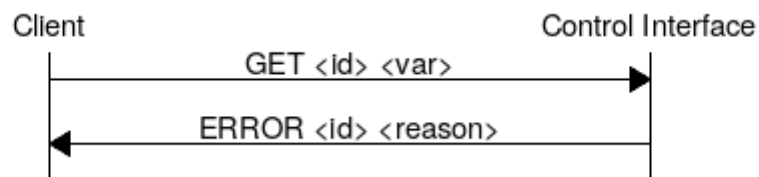


Figure 5: Control Interface GET operation (unsuccessful outcome)

6.1.2 SET operation

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

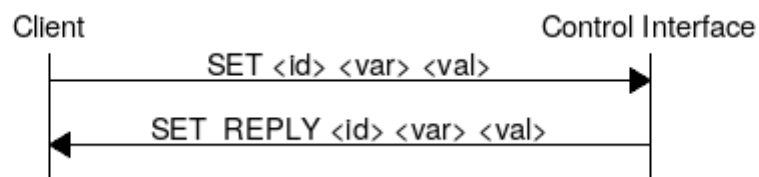


Figure 6: Control Interface SET operation (successful outcome)

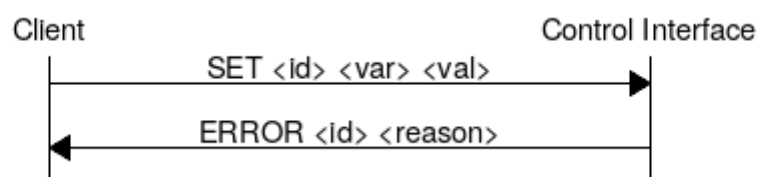


Figure 7: Control Interface SET operation (unsuccessful outcome)

6.1.3 TRAP operation

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

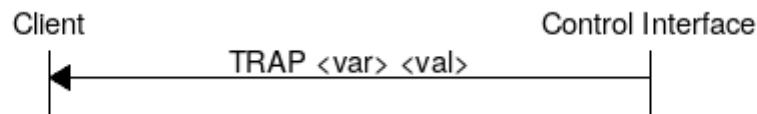


Figure 8: Control Interface TRAP operation

6.2 Common variables

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

Table 1: Variables available over control interface

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

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

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

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

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

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

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

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

6.3 Control Interface python examples

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

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

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

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

6.3.1 Getting rate counters

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

```
$ ./scripts/osmo_rate_ctr2csv.py --header
Connecting to localhost:4249...
Getting rate counter groups info...
"group","counter","absolute","second","minute","hour","day"
"elinp.0","hdlc:abort","0","0","0","0","0"
"elinp.0","hdlc:bad_fcs","0","0","0","0","0"
"elinp.0","hdlc:overrun","0","0","0","0","0"
"elinp.0","alarm","0","0","0","0","0"
"elinp.0","removed","0","0","0","0","0"
"bsc.0","chreq:total","0","0","0","0","0"
"bsc.0","chreq:no_channel","0","0","0","0","0"
...
"msc.0","call:active","0","0","0","0","0"
"msc.0","call:complete","0","0","0","0","0"
"msc.0","call:incomplete","0","0","0","0","0"
Completed: 44 counters from 3 groups received.
```

6.3.2 Setting a value

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

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

6.3.3 Getting a value

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

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

6.3.4 Listening for traps

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

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

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

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

7 Control interface

The actual protocol is described in Section 6, the variables common to all programs using it are described in Section 6.2. Here we describe variables specific to OsmoTRX.

Table 2: Variables available over control interface

Name	Access	Trap	Value	Comment
------	--------	------	-------	---------

8 The Osmocom VTY Interface

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

Note

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

The interactive telnet VTY is used to

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

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

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

Note

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

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

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

Table 3: VTY Parameter Patterns

Pattern	Example	Explanation
A.B.C.D	127.0.0.1	An IPv4 address
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

8.1 Accessing the telnet VTY

The VTY of a given Osmocom program is implemented as a telnet server, listening to a specific TCP port. For `osmo-nitb`, this port is 4242.

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

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



Warning

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

8.2 VTY Nodes

The VTY by default has the following minimal nodes:

VIEW

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

ENABLE

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

You can change back from the *ENABLE* node to the *VIEW* node by using the `disable` command.

CONFIG

The *CONFIG* node is entered by the `configure terminal` command from the *ENABLE* node. The config node is used to change the run-time configuration parameters of the system. The prompt will indicate that you are in the config node by a `(config)#` prompt suffix.

You can always leave the *CONFIG* node or any of its children by using the `end` command.

This node is also automatically entered at the time the configuration file is read. All configuration file lines are processed as if they were entered from the VTY *CONFIG* node at start-up.

Other

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

8.3 Interactive help

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

Note

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

8.3.1 The question-mark (?) command

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

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

Example: Typing ? at start of OsmoNITB prompt

```
OpenBSC> 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 log message to this terminal
  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

```
OpenBSC> show ❶
  version    Displays program version
  online-help Online help
  history    Display the session command history
  network    Display information about a GSM NETWORK
  bts        Display information about a BTS
  trx        Display information about a TRX
  timeslot   Display information about a TS
  lchan      Display information about a logical channel
  paging     Display information about paging requests of a BTS
  paging-group Display the paging group
  logging    Show current logging configuration
  alarms     Show current logging configuration
  stats      Show statistical values
  el_driver  Display information about available E1 drivers
  el_line    Display information about a E1 line
  el_timeslot Display information about a E1 timeslot
  subscriber Operations on a Subscriber
  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 network object and type ? again:

Example: Typing ? after show network

```
OpenBSC> show network
  <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".

8.3.2 TAB completion

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

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

```
OpenBSC> s
show      sms      subscriber
```

- 1 Type <tab> here.

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

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

```
OpenBSC> show
version   online-help history   network   bts       trx
timeslot  lchan     paging   paging-group logging   alarms
stats     el_driver el_line   el_timeslot subscriber statistics
sms-queue smpp
```

- 1 Type <tab> here.

8.3.3 The list command

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

Example: Typing list at start of OsmoNITB VIEW node prompt

```
OpenBSC> list
show version
show online-help
list
exit
help
enable
terminal length <0-512>
terminal no length
who
show history
show network
show bts [<0-255>]
show trx [<0-255>] [<0-255>]
show timeslot [<0-255>] [<0-255>] [<0-7>]
show lchan [<0-255>] [<0-255>] [<0-7>] [lchan_nr]
show lchan summary [<0-255>] [<0-255>] [<0-7>] [lchan_nr]
show paging [<0-255>]
show paging-group <0-255> IMSI
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 set-log-mask MASK
logging level (all|rll|cc|mm|rr|rs|nm|mncc|pag|meas|sccp|msc|mgcp|ho|db|ref|gprs|ns|
  bssgp|llc|sndcp|nat|ctrl|smpp|filter|lglobal|llapd|linp|lmux|lmi|lmib|lsms|lctrl|lgtp|
  lstats) (debug|info|notice|error|fatal)
```

```

show logging vty
show alarms
show stats
show stats level (global|peer|subscriber)
show e1_driver
show e1_line [line_nr] [stats]
show e1_timeslot [line_nr] [ts_nr]
show subscriber (extension|imsi|tmsi|id) ID
show subscriber cache
sms send pending
subscriber create imsi ID
subscriber (extension|imsi|tmsi|id) ID sms sender (extension|imsi|tmsi|id) SENDER_ID send ←
    .LINE
subscriber (extension|imsi|tmsi|id) ID silent-sms sender (extension|imsi|tmsi|id) ←
    SENDER_ID send .LINE
subscriber (extension|imsi|tmsi|id) ID silent-call start (any|tch/f|tch/any|sdch)
subscriber (extension|imsi|tmsi|id) ID silent-call stop
subscriber (extension|imsi|tmsi|id) ID ussd-notify (0|1|2) .TEXT
subscriber (extension|imsi|tmsi|id) ID update
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 OsmoNITB *VIEW* node with the list of the OsmoNITB *TRX* config node:

Example: Typing list at start of OsmoNITB TRX config node prompt

```

OpenBSC(config-net-bts-trx)# list
help
list
write terminal
write file
write memory
write
show running-config
exit
end
arfcn <0-1023>
description .TEXT
no description
nominal power <0-100>
max_power_red <0-100>
rsl e1 line E1_LINE timeslot <1-31> sub-slot (0|1|2|3|full)
rsl e1 tei <0-63>
rf_locked (0|1)
timeslot <0-7>

```

9 libosmocore Logging System

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

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

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

The logging system is composed of

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

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

9.1 Log categories

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

9.2 Log levels

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

fatal

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

error

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

notice

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

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`.

9.3 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`

9.4 Log targets

Each of the log targets represent certain destination for log messages. It can be configured independently by selecting levels (see Section 9.2) for categories (see Section 9.1) as well as filtering (see Section 9.3) and other options like `logging timestamp` for example.

9.4.1 Logging to the VTY

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

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

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

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

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

Finally, after having configured the levels, you still need to set the filter as it's described in Section 9.3.

Tip

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

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

9.4.2 Logging to the ring buffer

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

It's configured as follows:

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

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

9.4.3 Logging via gsmtap

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

It's configured as follows:

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

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

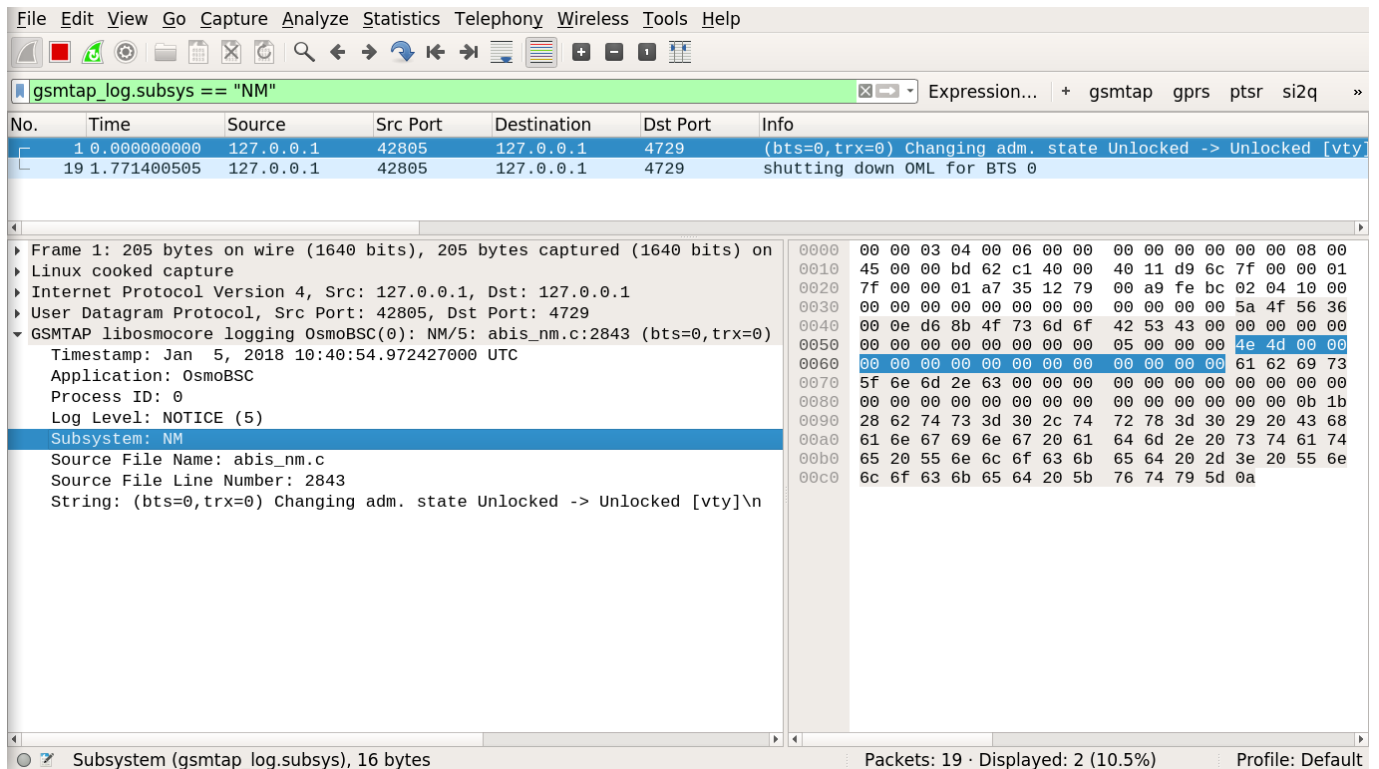


Figure 9: Wireshark with logs delivered over GSMTAP

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

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

9.4.4 Logging to a file

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

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

```
OsmoBSC> enable
OsmoBSC# configure terminal
```

```
OsmoBSC(config)# log file /path/to/my/file
OsmoBSC(config-log)#
```

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

Tip

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

Note

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

9.4.5 Logging to syslog

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

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

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

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

Note

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

9.4.6 Logging to stderr

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

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

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

10 Counters

These counters and their description based on OsmoTRX 0.2.0.61-408f (OsmoTRX).

11 Configuring OsmTRX

OsmoTRX will read the configuration at startup time and configure the transceiver accordingly after validating the configuration.

OsmoTRX can handle several TRX channels, but at least one must be configured in order to be able to start it successfully. Channels must be present in the configuration file in incremental order, starting from 0 and be consecutive.

Example configuration files for different devices and setups can be found in `doc/examples/` in `osmo-trx` git repository.

11.1 Documented example

Example: Static GGSN/APN configuration (single catch-all GGSN)

```
trx
bind-ip 127.0.0.1 ❶
remote-ip 127.0.0.1 ❷
base-port 5700 ❸
egprs disable ❹
tx-sps 4 ❺
rx-sps 4 ❻
chan 0 ❼
tx-path BAND1 ❽
rx-path LNAW ❾
```

- ❶ Configure the local IP address at the TRX used for the connection against `osmo-bts-trx`.
- ❷ Specify the IP address of `osmo-bts-trx` to connect to.
- ❸ Specify the reference base UDP port to use for communication.
- ❹ Don't enable EDGE support.
- ❺ Use 4 TX samples per symbol. This is device specific.
- ❻ Use 4 RX samples per symbol. This is device specific.
- ❼ Configure the first channel. As no other channels are specified, `osmo-trx` assumes it is using only one channel.
- ❽ Configure the device to use BAND1 Tx antenna path from all the available ones (device specific).
- ❾ Configure the device to use LNAW Rx antenna path from all the available ones (device specific).

11.2 Multi-ARFCN mode

The Multi-ARFCN feature allows to have a multi-carrier approach multiplexed on a single physical RF channel, which can introduce several benefits, such as lower cost and higher capacity support.

Multi-ARFCN support is available since `osmo-trx` release `0.2.0`, and it was added specifically in commit `76764278169d252980853251daeb9f1ba0c246e1`.

This feature is useful for instance if you want to run more than 1 TRX with an Ettus B200 device, or 3 TRX with an Ettus B210 device, since they support only 1 and 2 physical RF channels respectively. No device from other providers or even other devices than B200 and B210 from Ettus are known to support this feature.

With multi-ARFCN enabled, ARFCN spacing is fixed at 800 kHz or 4 GSM channels. So if TRX-0 is set to ARFCN 51, TRX-1 *must* be set to 55, and so on. Up to three ARFCN's is supported for multi-TRX.

From BTS and BSC point of view, supporting multiple TRX through multi-ARFCN feature in OsmoTRX doesn't make any difference from a regular multi-TRX setup, leaving apart of course the mentioned ARFCN limitations explained above and as a consequence physical installation and operational differences.

Example: `osmo-bts-trx.cfg` using 2 TRX against an `osmo-trx` driven device


```
phy 0
  osmotrx ip local 127.0.0.1
  osmotrx ip remote 127.0.0.1
  instance 0
  instance 1
bts 0
  ...
  band GSM-1800
  trx 0
    phy 0 instance 0
  trx 1
    phy 0 instance 1
```

Example: osmo-trx.cfg using Multi-ARFCN mode to run 2 TRX

```
trx
  ...
  multi-arfcn enable
  chan 0
  chan 1
```

12 OsmoTRX hardware architecture support

OsmoTRX comes out-of-the-box with several algorithms and operations optimized for certain instruction-set architectures, as well as non-optimized fall-back algorithms in case required instruction sets are not supported by the compiler at compile time or by the executing machine at run-time. Support for these optimized algorithms can be enabled and disabled by means of configure flags. Accelerated operations include pulse shape filtering, resampling, sequence correlation, and many other signal processing operations.

On Intel processors, OsmoTRX makes heavy use of the Streaming SIMD Extensions (SSE) instruction set. SSE3 is the minimum requirement for accelerated use. SSE3 is present in the majority of Intel processors since later versions of the Pentium 4 architecture and is also present on low power Atom processors. Support is automatically detected at build time. SSE4.1 instruction set is supported too. This feature is enabled by default unless explicitly disabled by passing the configure flag `--with-sse=no`. When enabled, the compiler will build an extra version of each of the supported algorithms using each of the supported mentioned instruction sets. Then, at run-time, OsmoTRX will auto-detect capabilities of the executing machine and enable an optimized algorithm using the most suitable available (previously compiled) instruction set.

On ARM processors, NEON and NEON FMA are supported. Different to the x86, there is no auto-detection in this case, nor difference between compile and runtime. NEON support is disabled by default and can be enabled by passing the flag `--with-neon=yes` to the configure script; the used compiler must support NEON instruction set and the resulting binary will only run fine on an ARM board supporting NEON extensions. Running OsmoTRX built with flag `--with-neon` on a board without NEON instruction set support, will most probably end up in the process being killed with a *SIGILL* Illegal Instruction signal by the operating system. NEON FMA (Fused Multiply-Add) is an extension to the NEON instruction set, and its use in OsmoTRX can be enabled by passing the `--with_neon_vfpv4` flag, which will also implicitly enable NEON support (`--with_neon`).

13 OsmoTRX hardware device support

OsmoTRX consists of a *common* part that applies to all TRX devices as well as *hardware-specific* parts for each TRX device. The hardware-specific parts are usually provided by vendor-specific or device-specific libraries that are then handled by some OsmoTRX glue code presenting a unified interface towards the rest of the code by means of a *RadioDevice* class.

The common part includes the core TRX architecture as well as code for implementing the external interfaces such as the TRX Manager UDP socket, control, and VTY interfaces.

The hardware-specific parts include support for driving one particular implementation of a radio modem. Such a physical layer implementation can come in many forms. Sometimes it runs on a general purpose CPU, sometimes on a dedicated ARM core, a dedicated DSP, a combination of DSP and FPGA.

Joining the common part with each of the available backends results in a different binary with different suffix for each backend. For instance, when OsmoTRX is built with UHD backend, an *osmo-trx-uhd* binary is generated; when OsmoTRX is built with LimeSuite backend, an *osmo-trx-lms* binary is generated. Build of different backend can be enabled and disabled by means of configure flags, which can be found in each subsection relative to each backend below.

13.1 Ettus USRP1

The binary *osmo-trx-usrp1* is used to drive this device, see Section 14.3.

13.2 Ettus B200

The binary *osmo-trx-uhd* is used to drive this device, see Section 14.1.

Comes only with 1 RF channel. It can still be used in a multi-TRX setup by using the Section 11.2 feature. By using this feature, one can drive up to 3 TRX (with the restrictions explained there).

13.3 Ettus B210

The binary *osmo-trx-uhd* is used to drive this device, see Section 14.1.

Comes with 2 RF channels, which can be used to set up a multi-TRX BTS. However, due to a shared local oscillator for both RF channels, ARFCN separation can be up about 25 MHz.

This device also supports the Section 11.2 feature. By using this feature, one can drive up to 3 TRX (with the restrictions explained there). Please note that the above configurations cannot be combined, which means maximum number of TRX one can achieve is 2 by using separate physical RF channels, or 3 by using multi-ARFCN method. You cannot support, for example, 6 ARFCN operation on B210 using 3 TRX on side A and another 3 TRX on side B.

13.4 LimeSDR-USB

The binary *osmo-trx-lms* is used to drive this device, see Section 14.2.

This device comes with 2 RF channels, so it should theoretically be possible to run a multi-TRX setup with it, but there are yet no records that this kind of setup was tested with this device.

This device has 3 different Rx paths with different antenna connectors in the PCB, each with a different frequency and bandwidth range. One should make sure the physical antenna is connected to the correct connector matching the Rx path you want to use. If one wants to be able to use the device in both 900 and 1800 MHz GSM bands and easily switch between them, then Rx Path LNAW should be used, since it is the only one covering both bands, and the antenna physically plugged accordingly. Following example shows how to then configure *osmo-trx-lms* to use that Rx path to read samples.

Example: Configure *osmo-trx-lms* to use LNAW as Rx path and BAND1 as Tx Path

```
trx
...
chan 0
  tx-path BAND1
  rx-path LNAW
```

13.5 LimeSDR-mini

The binary *osmo-trx-lms* is used to drive this device, see Section 14.2.

As a smaller brother of the , this device comes only with 1 RF channel. As a result, it can only hold 1 TRX as of today.

14 OsmoTRX backend support

14.1 `osmo-trx-uhd` for UHD based Transceivers

This OsmoTRX model uses *libuhd* (UHD, USRP Hardware Driver) to drive the device, that is configuring it and reading/writing samples from/to it.

So far, this backend has been mostly used to drive devices such as the Ettus B200 family and Fairwaves UmTRX family, and used to be the default backend used for legacy `@osmo-trx@` binary when per-backend binaries didn't exist yet.

Any device providing generic support for UHD should theoretically be able to be run through this backend without much effort, but practical experience showed that some devices don't play well with it, such as the LimeSDR family of devices, which showed far better results when using its native interface.

Related code can be found in the *Transceiver52M/device/uhd/* directory in *osmo-trx.git*.

14.2 `osmo-trx-lms` for LimeSuite based Transceivers

This OsmoTRX model uses LimeSuite API and library to drive the device, that is configuring it and reading/writing samples from/to it.

This backend was developed in order to be used together with LimeSDR-USB and LimeSDR-mini devices, due to the poor results obtained with the UHD backend, and to simplify the stack.

Related code can be found in the *Transceiver52M/device/lms/* directory in *osmo-trx.git*.

14.3 `osmo-trx-usrp1` for libusrp based Transceivers

This OsmoTRX model uses the legacy libusrp driver provided in GNU Radio 3.4.2.

As this code was dropped from GNU Radio at some point and was found very difficult to build, some work was done to create a standalone libusrp which can be nowadays found as a separate git repository together with other osmocom git repositories, in <https://git.osmocom.org/libusrp/>

Related code can be found in the *Transceiver52M/device/usrp1/* directory in *osmo-trx.git*.

15 Code Architecture

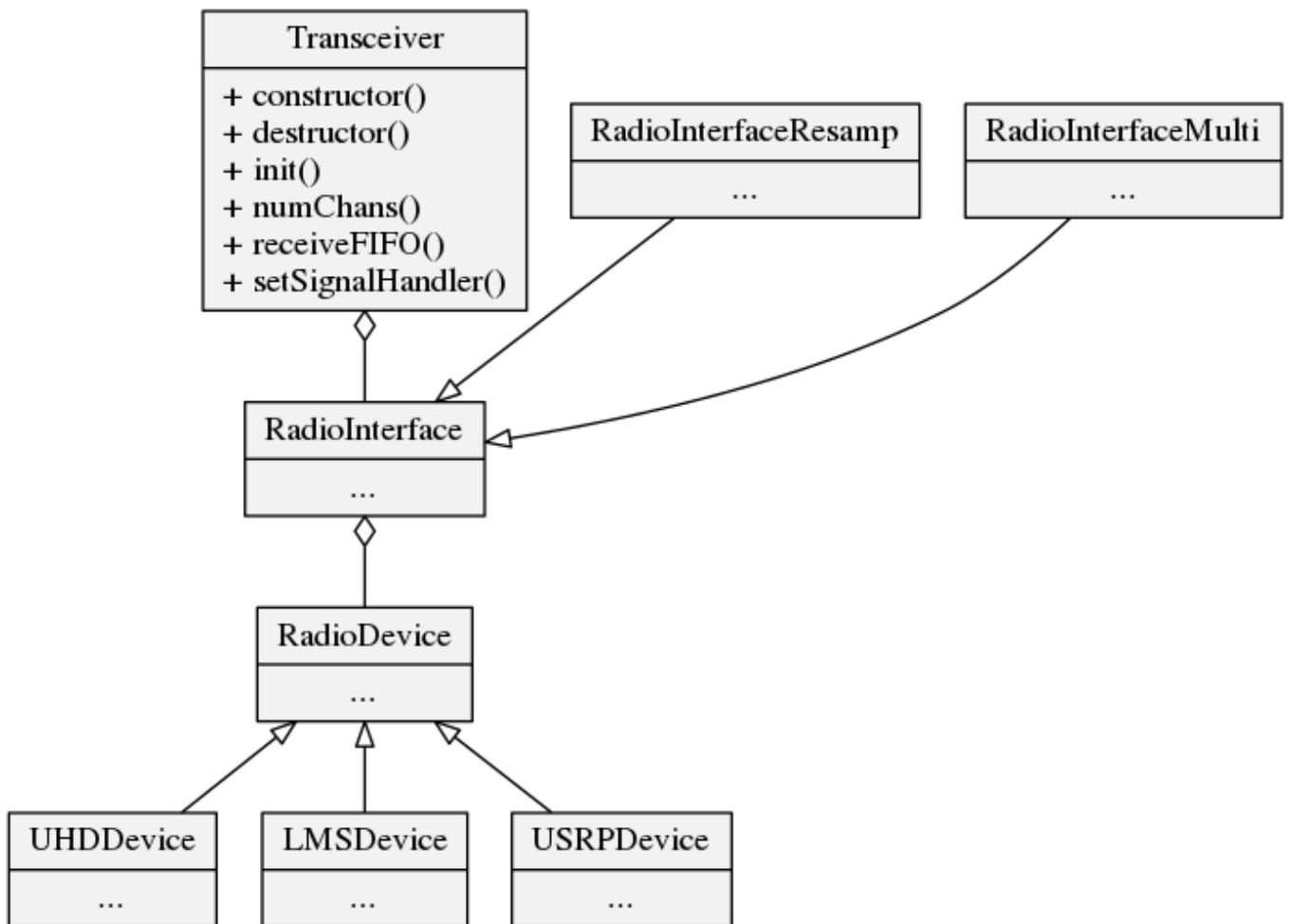


Figure 10: General overview of main OsmoTRX components

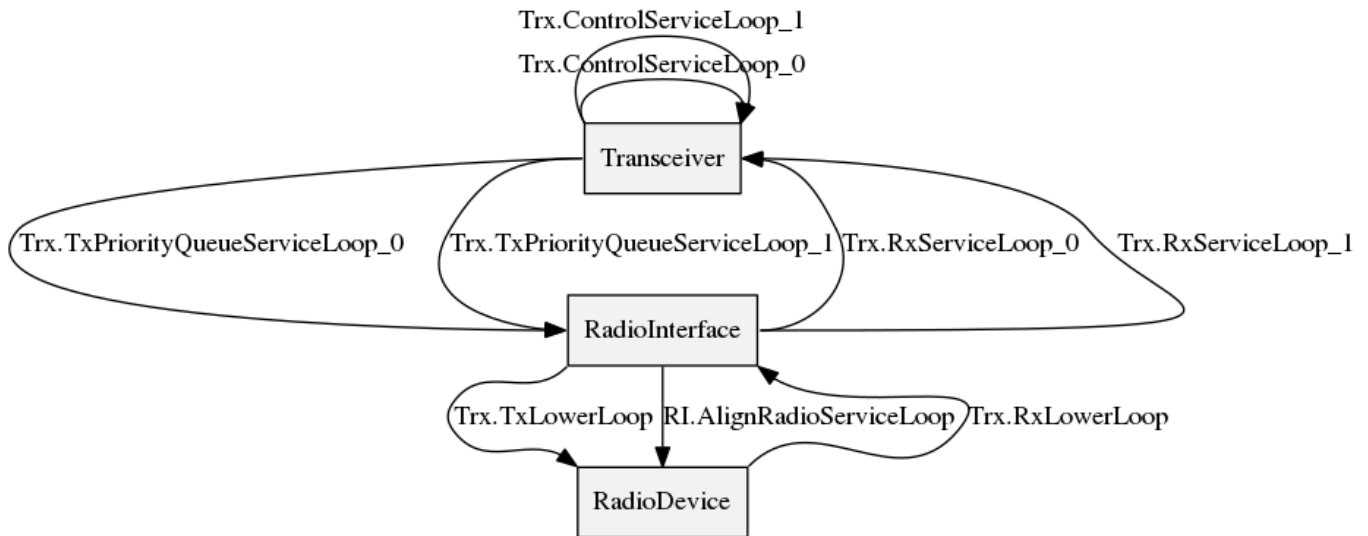


Figure 11: Example of thread architecture with OsmoTRX configured to use 2 logical RF channels (Trx=Transceiver, RI=RadioInterface)

15.1 Transceiver

The Transceiver is the main component managing the other components running in the OsmoTRX process. There's a unique instance per process.

This class is quite complex from code point of view, as it starts lots of different threads and hence the interaction with this class from the outside is quite limited. Only interaction possible is to:

- `Transceiver()`: Create an instance through its constructor, at this time most configuration is handed to it.
- `init()`: Start running all the threads.
- `receiveFIFO()`: Attach a `radioInterface` channel FIFO in order to use it.
- `setSignalHandler()`: Used to set up a callback to receive certain events asynchronously from the Transceiver. No assumptions can be made about from which thread is the callback being called, which means multi-thread locking precautions may be required in certain cases, similar to usual signal handler processing. One important event received through this path is for instance when the Transceiver detected a fatal error which requires it to stop. Since it cannot stop itself (see destructor below), stopping procedure must be delegated to the user who created the instance.
- `~Transceiver()`: The destructor, which stops all running threads created at `init()` time. Destroying the object is the only way to stop the Transceiver completely, and must be called from a thread not managed by the Transceiver, otherwise it will deadlock. Usually it is stopped from the main thread, the one that called the constructor during startup.

During `init()` time, `Transceiver` will create a noticeable amount of threads, which may vary depending on the amount of RF channels requested.

Static amount of Threads (1 per `Transceiver` instance):

- `RxLowerLoop`: This thread is responsible for reading bursts from the `RadioInterface`, storing them into its FIFO and sending Clock Indications (Section 16.1) to `osmo-bts_trx`.
- `TxLowerLoop`: Manages pushing bursts from buffers in the FIFO into the `RadioInterface` at expected correct time based on the Transceiver clock.

Dynamic amount of Threads (1 per RF logical channel on the `Transceiver` instance):

- `ControlServiceLoop`: Handles commands from the Per-ARFCN Control Interface socket (Section 16.2). Each thread is responsible for managing one socket related to one ARFCN or which is the same, to one RF logical channel. These are the only threads expected to use the private `start()` and `stop()` methods of the `Transceiver()` class, since those methods don't stop any of the `ControlServiceLoop` threads as they must keep running to handle new commands (for instance, to re-start processing samples with the `POWERON` command).
- `RxServiceLoop`: Each thread of this type pulls bursts from the `RadioInterface` FIFO for one specific logical RF channel and handles it according to the slot and burst correlation type, finally sending proper data over the TRX Manager UDP socket (Section 16).
- `TxPriorityQueueServiceLoop`: Blocks reading from one ARFCN specific TRX Manager UDP socket (Section 16), and fills the `RadioInterface` with it setting clock related information.

15.2 RadioInterface

The `RadioInterface` sits between the `Transceiver` and the `RadioDevice`, and provides extra features to the pipe like channelizers, resamplers, Tx/Rx synchronization on some devices, etc.

If the `RadioDevice` it drives requires it (only *USRP1* so far), the `RadioInterface` will start and manage a thread internally called `AlignRadioServiceLoop` which will align current RX and TX timestamps.

Different features are offered through different `RadioInterface` subclasses which are selected based on configuration and device detected at runtime. Using these features may impact on the amount of CPU required to run the entire pipe.

15.2.1 RadioInterfaceResamp

This subclass of `RadioInterface` is automatically selected when some known specific UHD are to be used, since they require resampling to work properly. Some of this devices are for instance Ettus B100, USRP2 and X3XX models.

15.2.2 RadioInterfaceMulti

This subclass of `RadioInterface` is used when Section 11.2 is requested.

15.3 RadioDevice

The `RadioDevice` class is responsible for driving the actual Hardware device. It is actually only an interface, and it is implemented in each backend which in turn becomes a specific OsmoTRX binary, see Section 14.

16 TRX Manager UDP socket interface

This is the protocol used between `osmo-trx` and `osmo-bts-trx`.

Each TRX Manager UDP socket interface represents a single ARFCN. Each of these per-ARFCN interfaces is a pair of UDP sockets, one for control and one for data. Given a base port B (5700), the master clock interface is at port P=B. The TRX-side control interface for C(N) is on port P=B+2N+1 and the data interface is on an odd numbered port P=B+2N+2. The corresponding core-side interface for every socket is at P+100. For any given build, the number of ARFCN interfaces can be fixed.

16.1 Indications on the Master Clock Interface

The master clock interface is output only (from the radio). Messages are "indications".

CLOCK gives the current value of the transceiver clock to be used by the core. This message is sent whenever a transmission packet arrives that is too late or too early. The clock value is NOT the current transceiver time. It is a time setting the the core should use to give better packet arrival times.

```
IND CLOCK <totalFrames>
```

16.2 Commands on the Per-ARFCN Control Interface

The per-ARFCN control interface uses a command-reponse protocol. Commands are NULL-terminated ASCII strings, one per UDP socket. Each command has a corresponding response.

Every command is of the form:

```
CMD <cmdtype> [params]
```

The <cmdtype> is the actual command. Parameters are optional depending on the commands type. Every response is of the form:

```
RSP <cmdtype> <status> [result]
```

The <status> is 0 for success and a non-zero error code for failure. Successful responses may include results, depending on the command type.

16.2.1 Power Control

POWEROFF shuts off transmitter power and stops the demodulator.

```
CMD POWEROFF
RSP POWEROFF <status>
```

POWERON starts the transmitter and starts the demodulator. Initial power level is very low. This command fails if the transmitter and receiver are not yet tuned. This command fails if the transmit or receive frequency creates a conflict with another ARFCN that is already running. If the transceiver is already on, it response with success to this command.

```
CMD POWERON
RSP POWERON <status>
```

SETPOWER sets output power in dB wrt full scale. This command fails if the transmitter and receiver are not running.

```
CMD SETPOWER <dB>
RSP SETPOWER <status> <dB>
```

ADJPOWER adjusts power by the given dB step. Response returns resulting power level wrt full scale. This command fails if the transmitter and receiver are not running.

```
CMD ADJPOWER <dBStep>
RSP ADJPOWER <status> <dBLevel>
```

16.2.2 Tuning Control

RXTUNE tunes the receiver to a given frequency in kHz. This command fails if the receiver is already running. (To re-tune you stop the radio, re-tune, and restart.) This command fails if the transmit or receive frequency creates a conflict with another ARFCN that is already running.

```
CMD RXTUNE <kHz>
RSP RXTUNE <status> <kHz>
```

TXTUNE tunes the transmitter to a given frequency in kHz. This command fails if the transmitter is already running. (To re-tune you stop the radio, re-tune, and restart.) This command fails if the transmit or receive frequency creates a conflict with another ARFCN that is already running.

```
CMD TXTUNE <kHz>
RSP TXTUNE <status> <kHz>
```

16.2.3 Timeslot Control

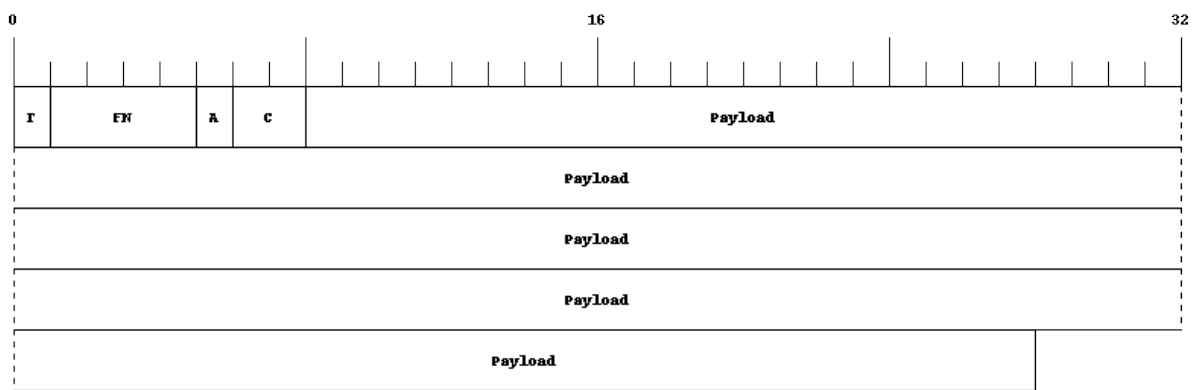
SETSLOT sets the format of the uplink timeslots in the ARFCN. The <timeslot> indicates the timeslot of interest. The <chantype> indicates the type of channel that occupies the timeslot. A chantype of zero indicates the timeslot is off.

```
CMD SETSLOT <timeslot> <chantype>
RSP SETSLOT <status> <timeslot> <chantype>
```

16.3 Messages on the per-ARFCN Data Interface

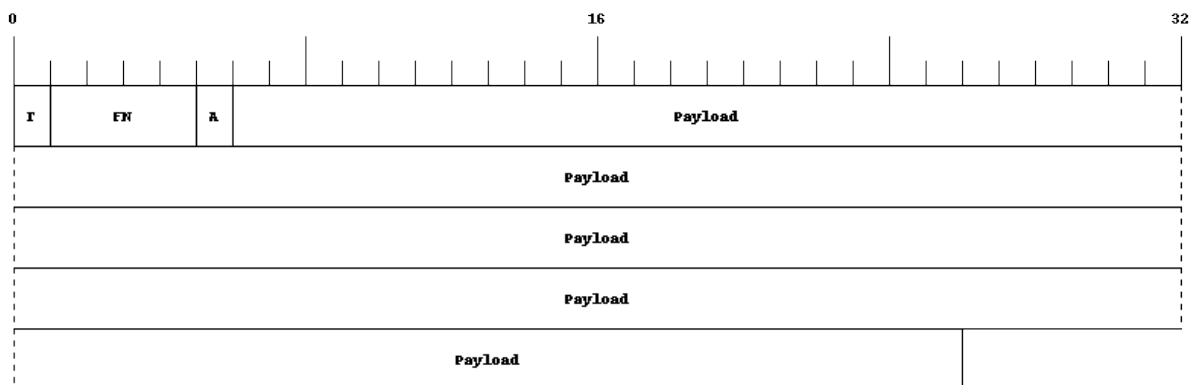
Messages on the data interface carry one radio burst per UDP message.

16.3.1 Received Data Burst



- *T*: timeslot index
- *FN*: GSM frame number, big endian
- *A*: RSSI in -dBm
- *C*: correlator timing offset in 1/256 symbol steps, 2's-comp, big endian
- *Payload*: 148 bytes soft symbol estimates, 0 → definite "0", 255 → definite "1"

16.3.2 Transmit Data Burst



- *T*: timeslot index
- *FN* GSM frame number, big endian
- *A*: transmit level wrt ARFCN max, -dB (attenuation)
- *Payload*: 148 bytes output symbol values, 0 & 1

17 Glossary

2FF

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

3FF

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

3GPP

3rd Generation Partnership Project

4FF

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

A Interface

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

A3/A8

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

A5

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

Abis Interface

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

ACC

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

AGCH

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

AGPL

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

ARFCN

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

AUC

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

BCCH

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

BCC

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

BTS

Base Transceiver Station

BSC

Base Station Controller

BSIC

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

BSSGP

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

BVCI

BSSGP Virtual Circuit Identifier

CBCH

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

CC

Call Control; Part of the GSM Layer 3 Protocol

CCCH

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

Cell

A cell in a cellular network, served by a BTS

CEPT

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

CGI

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

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

DSP

Digital Signal Processor

dnixload

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

ESME

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

ETSI

European Telecommunications Standardization Institute

FPGA

Field Programmable Gate Array; programmable digital logic hardware

Gb

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

GERAN

GPRS/EDGE Radio Access Network

GFDL

GNU Free Documentation License; a copyleft-style Documentation License

GGSN

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

GMSK

Gaussian Minimum Shift Keying; modulation used for GSM and GPRS

GPL

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

Gp

Gp interface between SGSN and GGSN; uses GTP protocol

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

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

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 identifier for the mobile phone

IMSI

International Mobile Subscriber Identity; 15-digit unique identifier for the subscriber/SIM; starts with MCC/MNC of issuing operator

IP

Internet Protocol (*IETF RFC 791* [?])

IPA

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

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

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

MMF

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

MNO

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

MS

Mobile Station; a mobile phone / GSM Modem

MSC

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

MSISDN

Mobile Subscriber ISDN Number; telephone number of the subscriber

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

NSEI

NS Entity Identifier

NVCI

NS Virtual Circuit Identifier

NWL

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

NS

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

OCXO

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

OML

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

OpenBSC

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

OpenGGSN

Open Source implementation of a GPRS Packet Control Unit

OpenVPN

Open-Source Virtual Private Network; software employed to establish encrypted private networks over untrusted public networks

Osmocom

Open Source MOBILE COMmunications; collaborative community for implementing communications protocols and systems, including GSM, GPRS, TETRA, DECT, GMR and others

OsmoBSC

Open Source implementation of a GSM Base Station Controller

OsmoNITB

Open Source implementation of a GSM Network In The Box, combines functionality traditionally provided by BSC, MSC, VLR, HLR, AUC, SMSC

OsmoSGSN

Open Source implementation of a Serving GPRS Support Node

OsmoPCU

Open Source implementation of a GPRS Packet Control Unit

OTA

Over-The-Air; Capability of operators to remotely reconfigure/reprogram ISM/USIM cards

PC

Point Code; an address in MTP

PCH

Paging Channel on downlink Um interface; used by network to page an MS

PCU

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

PDCH

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

PIN

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

PLMN

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

PUK

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

RAC

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

RACH

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

RAM

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

RF

Radio Frequency

RFM

Remote File Management; Ability to remotely manage (write, read) files on a SIM/USIM card

Roaming

Procedure in which a subscriber of one network is using the radio network of another network, often in different countries; in some countries national roaming exists

Routing Area

Routing Area; GPRS specific sub-division of Location Area

RR

Radio Resources; Part of the GSM Layer 3 Protocol

RSL

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

RTP

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

SACCH

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

SCCP

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

SDCCH

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

SDK

Software Development Kit

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

SSH

Secure Shell; *IETF RFC 4250* [[ietf-rfc4251](#)] to 4254

SSN

Sub-System Number; identifies a given SCCP Service such as MSC, HLR

STP

Signaling Transfer Point; A Router in SS7 Networks

SUA

SCCP User Adaptation; a SIGTRAN Variant (*RFC 3868* [[ietf-rfc3868](#)])

syslog

System logging service of UNIX-like operating systems

System Information

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

TCH

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

TCP

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

TFTP

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

TRX

Transceiver; element of a BTS serving a single carrier

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

VCTCXO

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

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 4: TCP/UDP port numbers

L4 Protocol	Port Number	Purpose	Software
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	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
UDP	4729	GSMTAP	Almost every osmocom project
TCP	5000	A/IP	osmo-bsc, osmo-bsc_nat
UDP	2427	GSMTAP	osmo-pcu, osmo-bts
UDP	23000	GPRS-NS over IP default port	osmo-pcu, osmo-sgsn, osmo-gbproxy

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