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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.
• 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

• 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.
2.2 Osmocom and sysmocom

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

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

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

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

2.3 Corrections

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

2.4 Legal disclaimers

2.4.1 Spectrum License

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

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

2.4.2 Software License

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

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

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

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

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

2.4.3 Trademarks

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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 syston (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 syston helps to cover the ongoing maintenance of the Osmocom CNI software stack.

4 Overview

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

4.1 About OsmoMSC

OsmoMSC is the Osmocom implementation of a Mobile Switching Center (MSC) for 2G and 3G GSM and UMTS mobile networks. Its interfaces are:

- GSUP towards OsmoHLR (or a MAP proxy);
- A over IP towards a BSC (e.g. OsmoBSC);
- IuCS towards an RNC or HNB-GW (e.g. OsmoHNBGW) for 3G voice;
- MNCC (Mobile Network Call Control derived from GSM TS 04.07);
- SMPP 3.4 (Short Message Peer-to-Peer);
- The Osmocom typical telnet VTY and CTRL interfaces.

OsmoMSC originated from the OpenBSC project, which started as a minimalistic all-in-one implementation of the GSM Network. In 2017, OpenBSC had reached maturity and diversity (including M3UA SIGTRAN and 3G support in the form of IuCS and IuPS interfaces) that naturally lead to a separation of the all-in-one approach to fully independent separate programs as in typical GSM networks. Before it was split off, OsmoMSC originated from libmsc of the old openbsc.git. Since a true A interface and IuCS for 3G support is available, OsmoMSC exists only as a separate standalone entity.

Key differences of the new OsmoMSC compared to the old OsmoNITB are:

- The complete VLR implementation that communicates with the separate HLR (OsmoHLR) for subscriber management. In contrast to the OsmoNITB, HLR queries are fully asynchronous, and the separate HLR allows using centralized subscriber management for both circuit-switched and packet-switched domains (i.e. one OsmoHLR for both OsmoMSC and OsmoS-GSN).

- VLR and HLR brought full UMTS AKA (Authentication and Key Agreement) support, i.e. Milenage authentication in both the full 3G variant as well as the backwards compatible 2G variant.

- Addition of a true A interface for 2G voice services. Previously, OsmoBSC had an SCCPlite based A interface towards 3rd party MSC implementations. OsmoMSC features a true SCCP/M3UA A interface, which allows running OsmoBSC against this Osmocom based MSC implementation. The new SCCP/M3UA SIGTRAN for the A interface is implemented in libosmo-sccp, which is used by OsmoMSC and OsmoBSC (and others), to establish a link via an STP (e.g. OsmoSTP).

- Addition of an IuCS interface to allow operating 3G voice services, also via SCCP/M3UA SIGTRAN, for example connecting via OsmoHNBGW to a 3G small cell device.
Find the OsmoMSC issue tracker and wiki online at

- https://osmocom.org/projects/osmomsc
- https://osmocom.org/projects/osmomsc/wiki

![Typical GSM network architecture used with OsmoMSC](image)

**Figure 1: Typical GSM network architecture used with OsmoMSC**

### 4.2 Software Components

This is a brief description of OsmoMSC’s internal software components.

#### 4.2.1 SMSC

A minimal store-and-forward server for SMS, supporting both MO and MT SMS service, as well as multi-part messages. The built-in SMSC also supports an external SMSC interface. For more information, see Section 17.

#### 4.2.2 MSC

The MSC component implements the mobility management (MM) functions of the TS 04.08 and delegates to SMSC for SMS message handling and the VLR for subscriber management.

Furthermore, it can handle TS 04.08 Call Control (CC), either by use of an internal MNCC handler, or by use of an external MNCC agent. For more information see Section 18.

#### 4.2.3 VLR

A fully featured Visitor Location Register handles the subscriber management and authentication, and interfaces via GSUP to the external HLR.

### 5 Running OsmoMSC

The OsmoMSC executable (`osmo-msc`) offers the following command-line arguments:

#### 5.1 SYNOPSIS

```
```
5.2 OPTIONS

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

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

-d, --debug DBGMASK DBGLEVELS
Set the log subsystems and levels for logging to stderr. This has mostly been superseded by VTY-based logging configuration, see Section 12 for further information.

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

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

-s, --disable-color
Disable colors for logging to stderr. This has mostly been deprecated by VTY based logging configuration, see Section 12 for more information.

-T, --timestamp
Enable time-stamping of log messages to stderr. This has mostly been deprecated by VTY based logging configuration, see Section 12 for more information.

-e, --log-level LOGLEVEL
Set the global log level for logging to stderr. This has mostly been deprecated by VTY based logging configuration, see Section 12 for more information.

5.3 Multiple instances

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

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

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

If external SMPP is enabled, you may bind it to a different interface using:

```
smpp
  local-tcp-ip 10.23.42.1 2775
```

More on SMPP configuration in [?].

The external MNCC handler is a UNIX domain socket that is created when external MNCC handling is configured. A separate path must be used per osmo-msc instance:

```
msc
  mncc external /tmp/mncc_socket
```
More on MNCC in Section 18.2.

The SGs interface by default listens on 0.0.0.0:29118 (SCTP). Each instance of OsmoMSC must use a different IP address and/or port. For details about the configuration of the SGs interface, see section Section 21.

For the following links, OsmoMSC acts as a client and does not listen/bind to a specific interface, and will hence not encounter conflicts for multiple instances running on the same interface:

- The SCCP/M3UA links are established by OsmoMSC contacting an STP.
- The GSUP link is established by OsmoMSC contacting an HLR.
- The MGCP link is established by OsmoMSC contacting an MGW.

5.4 Configure primary links

5.4.1 Configure SCCP/M3UA to accept A and IuCS links

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

An example configuration of OsmoMSC’s SCCP link:

```
cs7 instance 0
    point-code 0.23.1
    asp asp-clnt-OsmoMSC-A-Iu 2905 0 m3ua
    remote-ip 127.0.0.1
    role asp
    sctp-role client
```

This configuration is explained in detail in Section 15.

Note that A and IuCS may use different SCCP instances, if so desired:

```
cs7 instance 0
    asp my-OsmoMSC-A 2905 0 m3ua
    remote-ip 10.23.42.1
    role asp
    sctp-role client

cs7 instance 1
    asp my-OsmoMSC-Iu 2905 0 m3ua
    remote-ip 10.23.42.2
    role asp
    sctp-role client
```

```
msc
    cs7-instance-a 0
    cs7-instance-iu 1
```

5.4.2 Configure GSUP to reach the HLR

OsmoMSC will assume a GSUP server (OsmoHLR) to run on the local host and the default GSUP port (4222). Contacting an HLR at a different IP address can be configured as follows:

```
hlr
    ! IP address of the remote HLR:
    remote-ip 10.23.42.1
    ! default port is 4222, optionally configurable by:
    remote-port 1234
```
5.4.3 Configure MGCP to connect to an MGW

OsmoMSC uses a media gateway (typically OsmoMGW) to direct RTP streams. By default, an MGW is expected to receive MGCP requests on the IANA-registered default port for MGCP (2427) on local host (127.0.0.1).

Here is an example configuration for a remote MGW:

```
network
mgw 0
remote-ip 10.9.8.7
remote-port 2427
reset-endpoint rtpbridge/*/v
```

The `reset-endpoint` setting instructs the OsmoMGW to send a wildcarded DLCX to the media gateway. This helps to clear lingering calls from the media gateway when the OsmoMSC is restarted.

OsmoMSC is also able to handle a pool of media gateways for load distribution. See also Section 20.

---

**Note**

Previous versions of OsmoMSC (1.9.0 and below) didn’t have the `mgw` VTY node and hence didn’t support the MGW pooling feature. Therefore, historically the MGW related commands where placed under the `msc` VTY node. The MGW related commands under the `msc` VTY are still parsed and used but its use is deprecated and hence discouraged in favour of the new `mgw` node. Writing the config to a file from within OsmoMSC will automatically convert the config to use the new `mgw` node.

---

6 Control interface

The actual protocol is described in Section 22, the variables common to all programs using it are described in Section 22.2. This section describes the CTRL interface variables specific to OsmoMSC.

<table>
<thead>
<tr>
<th>Name</th>
<th>Access</th>
<th>Trap</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>subscriber-list-active-v1</td>
<td>RO</td>
<td>No</td>
<td></td>
<td>Return list of active subscribers.</td>
</tr>
</tbody>
</table>

6.1 `subscriber-list-active-v1`

Return a list of subscribers that are successfully attached (including full successful authentication and ciphering if those are enabled).

The reply comprises of one subscriber per line, of the format

```
<IMSI>,<MSISDN>
[<IMSI>,<MSISDN>
[...]]
```

For example:

```
901700000015252,22801
901700000015253,22802
```
7 Osmocom Counters

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

7.1 Osmo Counters (deprecated)

Osmo counters are the oldest type of counters added to Osmocom projects. They are not grouped.

- Printed as part of VTY show stats
- Increment, Decrement
- Accessible through the control interface: counter.<counter_name>

7.2 Rate Counters

Rate counters count rates of events.

- Printed as part of VTY show stats
- Intervals: per second, minute, hour, day or absolute value
- Increment only
- Accessible through the control interface
- Rate counters are grouped and different instances per group can exist

The control interface command to get a counter (group) is:

rate_ctr.per_{sec,min,hour,day,abs}.<group_name>.<idx>.[counter_name]

It is possible to get all counters in a group by omitting the counter name

7.3 Stat Item

Stat items are a grouped replacement for osmo counters.

- Printed as part of VTY show stats
- Replacement for osmo counters
- Not yet available through the control interface
- Grouped and indexed like rate counters
- Items have a unit
- Keeps a list of the last values measured, so could return an average, min, max, std. deviation. So far this is not implemented in any of the reporting options.

7.4 Statistic Levels

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

7.4.1 Global

These are global statistics.
7.4.2 Peer

These statistics relate to a peer the program connects to such as the NSVC in an SGSN. This level also includes reporting global statistics.

7.4.3 Subscriber

These statistics are related to an individual mobile subscriber. An example would be bytes transferred in an SGSN PDP context. This level also includes global and peer-based statistics.

7.5 Stats Reporter

The stats reporter periodically collects osmo counter, rate counter and stat item values and sends them to a backend. Currently implemented are outputting to the configured log targets and a statsd connector.

7.5.1 Configuring a stats reporter

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

**Example 7.1 Log statistics**

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

1. The interval determines how often the statistics are reported.
2. Write the statistic information to any configured log target.
3. Report only global statistics (can be global, peer, or subscriber).
4. Enable the reporter, disable will disable it again.

The counter values can also be sent to any aggregation/visualization tool that understands the statsd format, for example a statsd server with graphite or prometheus using the statsd_exporter together with grafana.

The statsd format is specified in [https://github.com/b/statsd_spec](https://github.com/b/statsd_spec).

**Example 7.2 Report statistics to statsd**

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

1. Configure the statsd reporter.
Prefix the reported statistics. This is useful to distinguish statistics from multiple instances of the same service.

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

IP address of the statsd server.

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

You can use Netdata (https://learn.netdata.cloud/) as a statsd server which does not require special configuration to show rate counters. By default all the rate counters will be exposed to the StatsD plugin (listening on 127.0.0.1:8125) and displayed on the Netdata dashboard available via: http://localhost:19999 The list of available charts which includes all the rate counters reported via statsD is available through: http://localhost:19999/api/v1/charts

7.6 Socket stats

libosmocore provides features to monitor the status of TCP connections. This can be a helpful source of information when the links between network components are unreliable (e.g. satellite link between BTS and BSC).

**Note**
This feature is only available for certain types of TCP connections. At the moment only RSL/OML connections between OsmoBSC and the connected BTSs can be monitored.

### 7.6.1 Configuration

The gathering of the TCP connection statistics is done via syscalls. This has to be taken into account for the configuration. Since syscalls are rather expensive and time consuming the overall performance of the application may suffer when many TCP connections are present. This may be the case for BSCs with a large number of BTSs connected to it.

The statistics are gathered in batches per interval. A batch size of 5 would mean that only 5 TCP connections per interval are evaluated and the next 5 connections in the next interval and so on.

It is recommended to choose a large reporting interval and a reasonable small batch size to distribute the syscall load as even as possible.

**Example 7.3 Report statistics to statsd**

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OsmoBSC&gt; enable</td>
<td></td>
</tr>
<tr>
<td>OsmoBSC# configure terminal</td>
<td></td>
</tr>
<tr>
<td>stats-tcp interval 10</td>
<td>Set the gathering interval (sec.)</td>
</tr>
<tr>
<td>stats-tcp batch-size 5</td>
<td>Set how many TCP sockets statistics to gather per interval.</td>
</tr>
</tbody>
</table>

### 7.6.2 Generated stats items

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tcp:unacked</td>
<td>unacknowledged packets.</td>
</tr>
<tr>
<td>tcp:lost</td>
<td>unacknowledged packets.</td>
</tr>
<tr>
<td>tcp:retrans</td>
<td>lost packets.</td>
</tr>
<tr>
<td>tcp:rtt</td>
<td>retransmitted packets.</td>
</tr>
<tr>
<td>tcp:rcv_rtt</td>
<td>roundtrip-time (receive).</td>
</tr>
<tr>
<td>tcp:notsent_bytes</td>
<td>bytes not yet sent.</td>
</tr>
</tbody>
</table>
The item group index is the file descriptor number. The item group name consists of a static prefix (e.g. "ipa-rsl"), followed by the IP addresses and ports of both peers.

**Example 7.4** VTY output of a stats item group of a TCP connection

```
stats tcp (15)('ipa-rsl,r=10.9.1.143:38455<>l=10.9.1.162:3003'):
  unacknowledged packets: 0
  lost packets: 0
  retransmitted packets: 0
  roundtrip-time: 583
  roundtrip-time (receive): 0
  bytes not yet sent: 0
  time (usec) limited by receive window: 0
  Time (usec) limited by send buffer: 0
  reordering events seen: 0
```

## 8 Counters

These counters and their description based on OsmoMSC 1.4.0 (OsmoMSC).

### 8.1 Rate Counters

Table 2: msc - mobile switching center

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>loc_update_type:attach</td>
<td>[?]</td>
<td>Received Location Update (IMSI Attach) requests.</td>
</tr>
<tr>
<td>loc_update_type:normal</td>
<td>[?]</td>
<td>Received Location Update (LAC change) requests.</td>
</tr>
<tr>
<td>loc_update_type:periodic</td>
<td>[?]</td>
<td>Received (periodic) Location Update requests.</td>
</tr>
<tr>
<td>loc_update_type:detach</td>
<td>[?]</td>
<td>Received IMSI Detach indications.</td>
</tr>
<tr>
<td>loc_update_resp:failed</td>
<td>[?]</td>
<td>Rejected Location Updates requests.</td>
</tr>
<tr>
<td>loc_update_resp:completed</td>
<td>[?]</td>
<td>Successful Location Update procedures.</td>
</tr>
<tr>
<td>cm_service_request:rejected</td>
<td>[?]</td>
<td>Rejected CM Service Requests.</td>
</tr>
<tr>
<td>cm_service_request:accepted</td>
<td>[?]</td>
<td>Accepted CM Service Requests.</td>
</tr>
<tr>
<td>paging_resp:rejected</td>
<td>[?]</td>
<td>Rejected Paging Responses.</td>
</tr>
<tr>
<td>paging_resp:accepted</td>
<td>[?]</td>
<td>Accepted Paging Responses.</td>
</tr>
<tr>
<td>sms:submitted</td>
<td>[?]</td>
<td>Total MO SMS received from the MS.</td>
</tr>
<tr>
<td>sms:no_receiver</td>
<td>[?]</td>
<td>Failed MO SMS delivery attempts (no receiver found).</td>
</tr>
<tr>
<td>sms:delivered</td>
<td>[?]</td>
<td>Total MT SMS delivery attempts.</td>
</tr>
<tr>
<td>sms:rp_err_mem</td>
<td>[?]</td>
<td>Failed MT SMS delivery attempts. (other reason).</td>
</tr>
</tbody>
</table>
Table 2: (continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sms:rp_err_other</td>
<td>[?]</td>
<td>Failed MT SMS delivery attempts (other reason).</td>
</tr>
<tr>
<td>call:mo_setup</td>
<td>[?]</td>
<td>Received MO SETUP messages (MO call establishment).</td>
</tr>
<tr>
<td>call:mo_connect_ack</td>
<td>[?]</td>
<td>Received MO CONNECT messages (MO call establishment).</td>
</tr>
<tr>
<td>call:mt_setup</td>
<td>[?]</td>
<td>Sent MT SETUP messages (MT call establishment).</td>
</tr>
<tr>
<td>call:mt_connect</td>
<td>[?]</td>
<td>Sent MT CONNECT messages (MT call establishment).</td>
</tr>
<tr>
<td>call:active</td>
<td>[?]</td>
<td>Calls that ever reached the active state.</td>
</tr>
<tr>
<td>call:complete</td>
<td>[?]</td>
<td>Calls terminated by DISCONNECT message after reaching the active state.</td>
</tr>
<tr>
<td>call:incomplete</td>
<td>[?]</td>
<td>Calls terminated by any other reason after reaching the active state.</td>
</tr>
<tr>
<td>nc_ss:mo_requests</td>
<td>[?]</td>
<td>Received MS-initiated call independent SS/USSD requests.</td>
</tr>
<tr>
<td>nc_ss:mo_established</td>
<td>[?]</td>
<td>Established MS-initiated call independent SS/USSD sessions.</td>
</tr>
<tr>
<td>nc_ss:mt_requests</td>
<td>[?]</td>
<td>Received network-initiated call independent SS/USSD requests.</td>
</tr>
<tr>
<td>nc_ss:mt_established</td>
<td>[?]</td>
<td>Established network-initiated call independent SS/USSD sessions.</td>
</tr>
<tr>
<td>bssmap:cipher_mode_reject</td>
<td>[?]</td>
<td>Number of CIPHER MODE REJECT messages processed by BSSMAP layer</td>
</tr>
<tr>
<td>bssmap:cipher_mode_complete</td>
<td>[?]</td>
<td>Number of CIPHER MODE COMPLETE messages processed by BSSMAP layer</td>
</tr>
</tbody>
</table>

9 Osmo Stat Items

10 Osmo Counters

Table 3: ungrouped osmo counters

<table>
<thead>
<tr>
<th>Name</th>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>msc.active_calls</td>
<td>[?]</td>
<td></td>
</tr>
<tr>
<td>msc.active_nc_ss</td>
<td>[?]</td>
<td></td>
</tr>
</tbody>
</table>

11 The Osmocom VTY Interface

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

The interactive telnet VTY is used to

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

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

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

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

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

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

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

The VTY of a given Osmocom program is implemented as a telnet server, listening to a specific TCP port. Please see Appendix A to check for the default TCP port number of the VTY interface of the specific Osmocom software you would like to connect to.

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

**Warning**

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

11.2 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.

11.3 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.
11.3.1 The question-mark (?) command

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

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

Example: Typing ? at start of OsmoMSC prompt

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

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 ?
    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
    taloc-context  Show taloc memory hierarchy
    stats          Show statistical values
    asciidoc       Asciidoc generation
    rate-counters  Show all rate counters
    fsm            Show information about finite state machines
    fsm-instances  Show information about finite state machine instances
    sgs-connections Show SGs interface connections / MMEs
    subscriber     Operations on a Subscriber
    bsc            BSC
    connection     Subscriber Connections
    transaction    Transactions
    statistics     Display network statistics
    sms-queue      Display SMSqueue statistics
    smpp           SMPP Interface
```

Type ? 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".
11.3.2 TAB completion

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

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

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

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

Type <tab> here.

11.3.3 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]
```
Tip
Remember, the list of available commands will change significantly depending on the Osmocom program you are accessing, its software version and the current node you're at. Compare the above example of the OsmoMSC VIEW node with the list of the OsmoMSC NETWORK config node:

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

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

11.3.4 The attribute system

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

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

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

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

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

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

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

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

```
OsmoBSC(config-net-bts)# list with-flags
. ... help
. ... list [with-flags]
. ... show vty-attributes
. ... show vty-attributes (application|library|global)
```
... write terminal
... write file [PATH]
... write memory
... write
... show running-config
... exit
... end
  0.. type {unknown|bs11|nanobts|rbs2000|nokia_site|sysmobts}
  ... description .TEXT
  ... no description
  0.. band BAND
  ... cell_identity <0-65535>
  ... dtx uplink [force]
  ... dtx downlink
  ... no dtx uplink
  ... no dtx downlink
  ... location_area_code <0-65535>
  ... base_station_id_code <0-63>
  ... ipa unit-id <0-65534> <0-255>
  ... ipa rsl-ip A.B.C.D
  ... nokia_site skip-reset (0|1)
  ! ... nokia_site no-local-rel-conf (0|1)
  ! ... nokia_site bts-reset-timer <15-100>

1. This command has no attributes assigned.
2. This command applies on A-bis OML link (re)establishment.
3. This command applies on A-bis RSL link (re)establishment.
4, 5. This command applies immediately.

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

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

11.3.5 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
OsmoBSC# list with-flags
...^ bts <0-255> (activate-all-lchan|deactivate-all-lchan)
^ bts <0-255> trx <0-255> (activate-all-lchan|deactivate-all-lchan)
This command enables the expert mode.

This is a hidden command (only shown in the expert mode).

This is a regular command that is always shown regardless of the mode.

### 12 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.

#### 12.1 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 ?`

#### 12.2 Log levels

For each of the log categories (see Section 12.1), you can set an independent log level, controlling the level of verbosity. Log levels include:

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

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

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

Some information about normal/regular system activity is provided.

debug

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

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

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

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

Afterwards you can adjust specific categories as usual.

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

12.3 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.

12.4 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`
12.5 Log targets

Each of the log targets represent certain destination for log messages. It can be configured independently by selecting levels (see Section 12.2) for categories (see Section 12.1) as well as filtering (see Section 12.4) and other options like logging timestamp for example.

12.5.1 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 12.1 for more details on categories and Section 12.2 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 12.4.

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
```

12.5.2 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.

12.5.3 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
containing GSMTAP logging together with other protocol traces to reconstruct exact chain of events. A single pcap file can then contain both the log output of any number of Osmocom programs in the same timeline of the messages on various interfaces in and out of said Osmocom programs.

It’s configured as follows:

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

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

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

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

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

```
OsmoBSC> enable
OsmoBSC# configure terminal
OsmoBSC(config)# log stderr
OsmoBSC(config-log)# logging level force-all fatal
```
Every time you generate GSMTAP messages and send it to a unicast (non-broadcast/multicast) IP address, please make sure that the destination IP address actually has a socket open on the specified port, or drops the packets in its packet filter. If unicast GSMTAP messages arrive at a closed destination UDP port, the operating system will likely generate ICMP port unreachable messages. Those ICMP messages in turn will, when arriving at the source (the host on which you run the Osmocom software sending GSMTAP), suppress generation of further GSMTAP messages for some time, resulting in incomplete files. In case of doubt, either send GSMTAP to multicast IP addresses, or run something like `nc -l -u -p 4729 > /dev/null` on the destination host to open the socket at the GSMTAP port and discard anything arriving at it.

12.5.4 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:

```shell
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.

12.5.5 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:

```shell
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.
12.5.6 Logging to systemd-journal

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

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


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

$ ./configure --enable-systemd-logging

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

You can configure systemd based logging in two ways:

**Example: systemd-journal target with offloaded rendering**

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

raw logging handler, rendering offloaded to systemd.

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

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

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

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

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

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

log systemd-journal 1
logging filter all 1
logging print file basename
logging print category-hex 0
logging print category 1
logging print level 1
logging timestamp 0 1
logging color 1
logging level set-all notice
Generic logging handler, rendering is done by libosmocore.

Disable timestamping, systemd will timestamp every message anyway.

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.

### 12.5.7 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:

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

### 13 Osmocom SS7 + SIGTRAN support

#### 13.1 History / Background

If you’re upgrading from earlier releases of the Osmocom stack, this section will give you some background about the evolution.

##### 13.1.1 The Past (before 2017)

In the original implementation of the GSM BSC inside Osmocom (the OsmoBSC program, part of OpenBSC), no SS7 support was included.

This is despite the fact that ETSI/3GPP mandated the use of SCCP over MTP over E1/T1 TDM lines for the A interface at that time.

Instead of going down to the TDM based legacy physical layers, OsmoBSC implemented something called an IPA multiplex, which apparently some people also refer to as SCCPlite. We have never seen any specifications for this interface, but implemented it from scratch using protocol traces.

The IPA protocol stack is based on a minimal sub-set of SCCP (including connection oriented SCCP) wrapped into a 3-byte header to packetize a TCP stream.

The IPA/SCCPlite based A interface existed at a time when the ETSI/3GPP specifications did not offer any IP based transport for the A interface. An official as added only in Release FIXME of the 3GPP specifications.

The A interface BSSMAP protocol refers to voice circuits (E1/T1 timeslots) using circuit identity codes (CICs). As there are no physical timeslots on a TCP/IP based transport layer, the CICs get mapped to RTP streams for circuit-switched data using out-of-band signaling via MGCP, the IETF-standardized Media Gateway Control Protocol.

##### 13.1.2 The present (2017)

In 2017, sysmocom was tasked with implementing a 3GPP AoIP compliant A interface. This meant that a lot of things had to change in the existing code:

- removal of the existing hard-wired SCCPlite/IPA code from OsmoBSC
- introduction of a formal SCCP User SAP at the lower boundary of BSSMAP
• introduction of libosmo-sigtran, a comprehensive SS7 and SIGTRAN library which includes a SCCP implementation for connectionless and connection-oriented procedures, offering the SCCP User SAP towards BSSAP
• introduction of an A interface in OsmoMSC (which so far offered Iu only)
• port of the existing SUA-based IuCS and IuPS over to the SCCP User SAP of libosmo-sigtran.
• Implementation of ETSI M3UA as preferred/primary transport layer for SCCP
• Implementation of an IPA transport layer inside libosmo-sigtran, in order to keep backwards-compatibility.

This work enables the Osmocom universe to become more compliant with modern Releases of 3GPP specifications, which enables interoperability with other MSCs or even BSCs. However, this comes at a price: Increased complexity in set-up and configuration.

Using SS7 or SIGTRAN based transport of the A interface adds an entirely new domain that needs to be understood by system and network administrators setting up cellular networks based on Osmocom.

One of the key advantages of the Osmocom architecture with OsmoNITB was exactly this simplification and reduction of complexity, enabling more people to set-up and operate cellular networks.

So we have put some thought into how we can achieve compatibility with SS7/SIGTRAN and the 3GPP specifications, while at the same time enabling some degree of auto-configuration where a small network can be set up without too many configuration related to the signaling network. We have achieved this by "abusing" (or extending) the M3UA Routing Key Management slightly.

13.2 Osmocom extensions to SIGTRAN

Osmocom has implemented some extensions to the SIGTRAN protocol suite. Those extensions will be documented below.

13.2.1 Osmocom M3UA Routing Key Management Extensions

In classic M3UA, a peer identifies its remote peer based on IP address and port details. So once an ASP connects to an SG, the SG will check if there is any configuration that matches the source IP (and possibly source port) of that connection in order to understand which routing context is used - and subsequently which traffic is to be routed to this M3UA peer.

This is quite inflexible, as it means that every BSC in a GSM network needs to be manually pre-configured at the SG/STP, and that configuration on the BSC and MSC must match to enable communication.

M3UA specifies an optional Routing Key Management (RKM) sub-protocol. Using RKM, an ASP can dynamically tell the SG/STP, which traffic it wants to receive. However, the idea is still that the SG has some matching configuration.

In OsmoSTP based on libosmo-sigtran, we decided to (optionally) enable fully dynamic registration. This means that any ASP can simply connect to the SG and request the dynamic creation of an ASP and AS with a corresponding routing key for a given point code. As long as the SG doesn’t already have a route to this requested point code, The SG will simply trust any ASP and set a corresponding route.

To enable dynamic creation of ASPs within an AS from any source IP/port, the corresponding xUA Server (Section 13.5) must be configured with accept-asp-connections dynamic-permitted.

To enable dynamic registration of routing keys via RKM, the corresponding SS7 Instance (Section 13.4) must be configured with xua rkm routing-key-allocation dynamic-permitted.

This is of course highly insecure and can only be used in trusted, internal networks. However, it is quite elegant in reducing the amount of configuration complexity. All that is needed, is that an unique point code is configured at each of the ASPs (application programs) that connect to the STP.

To put things more concretely: Each BSC and MSC connecting to OsmoSTP simply needs to be configured to have a different point code, and to know to which IP/port of the STP to connect. There’s no other configuration required for a small, autonomous, self-contained network. OsmoSTP will automatically install ASP, AS and route definitions on demand, and route messages between all connected entities.

The same above of course also applies to HNB-GW and OsmoSGSN in the case of Iu interfaces.
13.2.2 IPA / SCCPlite backwards compatibility

The fundamental problem with IPA/SCCPlite is that there’s no MTP routing label surrounding the SCCP message. This is generally problematic in the context of connection-oriented SCCP, as there is no addressing information inside the SCCP messages after the connection has been established. Instead, the messages are routed based on the MTP label, containing point codes established during connection set-up time.

This means that even if the SCCP messages did contain Called/Calling Party Addresses with point codes or global titles, it would only help us for routing connectionless SCCP. The A interface, however, is connection-oriented.

So in order to integrate IPA/SCCPlite with a new full-blown SS7/SIGTRAN stack, there are the following options:

1. implement SCCP connection coupling. This is something like a proxy for connection-oriented SCCP, and is what is used in SS7 to route beyond a given MTP network (e.g. at gateways between different MTP networks).
2. consider all SCCP messages to be destined for the local point code of the receiver. This then means that the SG functionality must be included inside the MSC, and the MSC be bound to the SSN on the local point code.
3. hard-code some DPC when receiving a message from an IPA connection. It could be any remote PC and we’d simply route the message towards that point code.

But then we also have the return direction:

1. We could “assign” a unique SPC to each connected IPA client (BSC), and then announce that PC towards the SS7 side. Return packets would then end up at our IPA-server-bearing STP, which forwards them to the respective IPA connection and thus BSC. On the transmit side, we’d simply strip the MTP routing label and send the raw SCCP message over IPA.
2. If the IPA server / SGW resides within the MSC, one could also have some kind of handle/reference to the specific TCP connection through which the BSC connected. All responses for a given peer would then have to be routed back to the same connection. This is quite ugly as it completely breaks the concepts of the SCCP User SAP, where a user has no information (nor to worry about) any “physical” signaling links.

13.3 Minimal Osmocom SIGTRAN configurations for small networks

If you’re not an SS7 expert, and all you want is to run your own small self-contained cellular network, this section explains what you need to do.

In general, you can consider OsmoSTP as something like an IP router. On the application layer (in our case the BSSAP/BSSMAP or RANAP protocols between Radio Access Network and Core Network), it is completely invisible/transparent. The BSC connects via SCCP to the MSC. It doesn’t know that there’s an STP in between, and that this STP is performing some routing function. Compares this to your web browser not knowing about IP routers, it just establishes an http connection to a web server.

This is also why most GSM network architecture diagrams will not explicitly show an STP. It is not part of the cellular network. Rather, one or many STPs are part of the underlying SS7 signaling transport network, on top of which the cellular network elements are built.

13.3.1 A minimal 2G configuration to get started

You will be running the following programs:

- OsmoBSC as the base-station controller between your BTS (possibly running OsmoBTS) and the MSC
- OsmoMSC as the mobile switching center providing SMS and telephony service to your subscribers
- OsmoSTP as the signal transfer point, routing messages between one or more BSCs and the MSC
You can use the OsmoSTP fully dynamic registration feature, so the BSCs and the MSC will simply register with their point codes to the STP, and the STP will create most configuration on the fly.

All you need to make sure is:

- to assign one unique point code to each BSC and MSC
- to point all BSCs and the MSC to connect to the IP+Port of the STP
- to configure the point code of the MSC in the BSCs

13.3.2 A minimal 3G configuration to get started

You will be running the following programs:

- OsmoHNBGW as the homeNodeB Gateway between your femtocells / small cells and the MSC+SGSN
- OsmoMSC as the mobile switching center providing SMS and telephony service to your subscribers
- OsmoSGSN as the Serving GPRS Support Node, providing packet data (internet) services to your subscribers
- OsmoSTP as the signal transfer point, routing messages between one or more HNBGWs and the MSC and SGSN

You can use the OsmoSTP fully dynamic registration feature, so the HNBGWs, the MSC and the SGSN will simply register with their point codes to the STP, and the STP will create most configuration on the fly.

All you need to make sure is:

- to assign one unique point code to each HNBGW, MSC and SGSN
- to point all HNBGWs and the MSC and SGSN to connect to the IP+Port of STP
- to configure the point code of the MSC in the HNBGWs
- to configure the point code of the SGSN in the HNBGWs
13.4 Osmocom SS7 Instances

The entire SS7 stack can be operated multiple times within one application/program by means of so-called SS7 Instances. There can be any number of SS7 Instances, and each instance has its own set of XUA Servers, ASPs, ASs, Routes, etc. Each SS7 Instance can have different point code formats / lengths.

Table 5: Major Attributes of an Osmocom SS7 Instance

<table>
<thead>
<tr>
<th>Name</th>
<th>VTY Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>(config)# cs7 instance ID</td>
<td>The numeric identifier of this instance</td>
</tr>
<tr>
<td>Name</td>
<td>(config-cs7)# name NAME</td>
<td>A human-readable name for this instance</td>
</tr>
<tr>
<td>Description</td>
<td>(config-cs7)# description DESC</td>
<td>More verbose description</td>
</tr>
<tr>
<td>Primary PC</td>
<td>(config-cs7)# point-code PC</td>
<td>Primary local point code</td>
</tr>
<tr>
<td>Network Indicator</td>
<td>(config-cs7)# network-indicator</td>
<td>Network Indicator used in MTP3 Routing Label</td>
</tr>
<tr>
<td>Point Code Format</td>
<td>(config-cs7)# point-code format</td>
<td>Point Code Format (Default: 3.8.3)</td>
</tr>
<tr>
<td>Point Code Delimiter</td>
<td>(config-cs7)# point-code delimiter</td>
<td>Point Code Delimiter: . or -</td>
</tr>
</tbody>
</table>

13.5 Osmocom SS7 xUA Server

A xUA Server is a server that binds + listens to a given SCTP (SIGTRAN) or TCP (IPA) port and accepts connections from remote peers (ASPs).

There can be any number of xUA Servers within one SS7 Instance, as long as they all run on a different combination of IP address and port.

Table 6: Major Attributes of an Osmocom SS7 xUA Server

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local IP</td>
<td>Local Port Number to which the server shall bind/listen</td>
</tr>
<tr>
<td>Local Port</td>
<td>Local IP Address to which the server shall bind/listen</td>
</tr>
<tr>
<td>Protocol</td>
<td>Protocol (M3UA, SUA, IPA) to be operated by this server</td>
</tr>
<tr>
<td>Accept Dynamic ASPs</td>
<td>Should we accept connections from ASPs that are not explicitly pre-configured with their source IP and port?</td>
</tr>
</tbody>
</table>

13.6 Osmocom SS7 Users

A SS7 User is part of a program that binds to a given MTP-Layer Service Indicator (SI). The Osmocom SS7 stack offers an API to register SS7 Users, as well as the VTY command `show cs7 instance <0-15> users` to list the currently registered users.

13.7 Osmocom SS7 Links

Conceptually, SS7 links are on the same level as SIGTRAN ASPs. The details of SS7 Links in the Osmocom implementation are TBD.
13.8 Osmocom SS7 Linksets

Conceptually, SS7 Linksets are on the same level as SIGTRAN ASs. The details of SS7 Links in the Osmocom implementation are TBD.

13.9 Osmocom SS7 Application Servers

This corresponds 1:1 to the SIGTRAN concept of an Application Server, i.e. a given external Application that interfaces the SS7 network via a SS7 protocol variant such as M3UA.

In the context of Osmocom, for each program connecting to a STP (like a BSC or MSC), you will have one Application Server definition.

An AS has the following properties:

Table 7: Major Attributes of an Osmocom SS7 Application Server

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>A human-readable name for this instance</td>
</tr>
<tr>
<td>Description</td>
<td>More verbose description (for human user only)</td>
</tr>
<tr>
<td>Protocol</td>
<td>Protocol (M3UA, SUA, IPA) to be operated by this server</td>
</tr>
<tr>
<td>Routing Key</td>
<td>Routing Key (mostly Point Code) routed to this AS</td>
</tr>
<tr>
<td>Traffic Mode</td>
<td>Broadcast, Loadshare or Override</td>
</tr>
<tr>
<td>Recovery Timeout</td>
<td>Duration of the AS T(r) recovery timer. During this time, outgoing messages are queued. If the AS is ACTIVE before timer expiration, the queue is drained. At expiration, the queue is flushed.</td>
</tr>
<tr>
<td>State</td>
<td>Application Server State (Down, Inactive, Active, Pending)</td>
</tr>
<tr>
<td>ASPs</td>
<td>Which ASPs are permitted to transfer traffic for this AS</td>
</tr>
</tbody>
</table>

13.10 Osmocom SS7 Application Server Processes

An Application Server Process corresponds to a given SCTP (or TCP) connection. From the STP/SG (Server) point-of-view, those are incoming connections from Application Servers such as the BSCs. From the ASP (Client) Point of view, it has one osmo_ss7_asp object for each outbound SIGTRAN connection.

An ASP has the following properties:

Table 8: Major Attributes of an Osmocom SS7 Application Server Process

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>A human-readable name for this instance</td>
</tr>
<tr>
<td>Description</td>
<td>More verbose description (for human user only)</td>
</tr>
<tr>
<td>Protocol</td>
<td>Protocol (M3UA, SUA, IPA) to be operated by this server</td>
</tr>
<tr>
<td>Role</td>
<td>Server (SG) or Client (ASP)?</td>
</tr>
<tr>
<td>Local Port</td>
<td>Port Number of the local end of the connection</td>
</tr>
<tr>
<td>Local IP</td>
<td>IP Address of the local end of the connection</td>
</tr>
<tr>
<td>Remote Port</td>
<td>Port Number of the remote end of the connection</td>
</tr>
<tr>
<td>Remote IP</td>
<td>IP Address of the remote end of the connection</td>
</tr>
<tr>
<td>State</td>
<td>ASP State (Down, Inactive, Active)</td>
</tr>
</tbody>
</table>
13.11 Osmocom SS7 Routes

An Osmocom SS7 Route routes traffic with a matching destination point code and point code mask (similar to IP Address + Netmask) towards a specified SS7 Linkset or Application Server. The Linkset or Application Servers are identified by their name.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point Code</td>
<td>Destination Point Code for this route</td>
</tr>
<tr>
<td>Mask</td>
<td>Destination Mask for this route (like an IP netmask)</td>
</tr>
<tr>
<td>Linkset/AS Name</td>
<td>Destination Linkset or AS, identified by name</td>
</tr>
</tbody>
</table>

13.12 Osmocom SCCP Instances

An Osmocom SCCP Instance can be bound to an Osmocom SS7 Instance. It will register/bind for the ITU-standard Service Indicator (SI).

13.13 Osmocom SCCP User

An Program (like a BSC) will bind itself to a given well-known sub-system number (SSN) in order to receive SCCP messages destined for this SSN.

There is an API to bind a program to a SSN, which implicitly generates an SCCP User object.

The `show cs7 instance <0-15> sccp users` command can be used on the VTY to obtain a list of currently bound SCCP users, as well as their corresponding SSNs.

13.14 Osmocom SCCP Connection

This is how Osmocom represents each individual connection of connection-oriented SCCP.

To illustrate the practical application: For the common use case of the A or Iu interfaces, this means that every dedicated radio channel that is currently active to any UE/MS has one SCCP connection to the MSC and/or SGSN.

The `show cs7 instance <0-15> sccp connections` command can be used on the VTY to obtain a list of currently active SCCP connections, as well as their source/destination and current state.

13.15 Osmocom SCCP User SAP

The Osmocom SCCP User SAP (Service Access Point) is the programming interface between the SCCP Provider (libosmo-sigtran) and the SCCP User (such as osmo-bsc, osmo-mse, osmo-hnb, etc.). It follows primitives as laid out in [itu-t-q711], encapsulated in osmo_prim structures.

13.16 Osmocom MTP User SAP

The Osmocom MTP User SAP (Service Access Point) is the programming interface between the MTP Provider and the MTP User (e.g. SCCP). It follows primitives as laid out in [itu-t-q711], encapsulated in osmo_prim structures.
14 Configure SCCP/M3UA

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

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

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

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

For example, in an all-Osmocom minimal setup,

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

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

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

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

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

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

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

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

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

### 14.1 Connect to STP Instance

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

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

Be aware that such an asp needs to be linked to an as, see Section 15.5.

By default, an STP instance is assumed to listen on the default M3UA port (2905) on the local host. That means in general 127.0.0.1 will be used as default remote SCTP address, and ::1 will be added to the SCTP association if IPv6 support is available on the system.

**Note**

OsmoSTP listens by default on :: if IPv6 is enabled on the system, and on 0.0.0.0 otherwise. Address :: actually superseeds 0.0.0.0, meaning it will listen on all IPv4 and IPv6 addresses available on the system.

**Caution**

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

### 14.2 Local Point-Code

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

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

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

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

See also Section 15.4.
14.3 Remote Point-Code

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

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

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

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

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

Examples:

- An OsmoBSC configures the MSC’s remote SCCP address:

  ```
cs7 instance 0
  sccp-address my-remote-msc
    point-code 1.23.1
  msc 0
  msc-addr my-remote-msc
  ```

- An HNBGW configures both the remote MSC’s and SGSN’s SCCP addresses:

  ```
cs7 instance 0
  sccp-address my-msc
    point-code 0.23.1
  sccp-address my-sgsn
    point-code 0.23.2
  hnbgw
    iuca
      remote-addr my-msc
    iups
      remote-addr my-sgsn
  ```

Besides a point-code, an SCCP address can have several routing indicators:

- PC: routing by point-code is the default for Osmocom.
- GT: routing by Global Title is configurable by `routing-indicator GT`.
- IP: routing by IP address is configurable by `routing-indicator IP`.

In OsmoSTP, only routing by point-code is currently implemented.


14.4 Point-Code Format

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

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

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

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

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

It is also possible to use a dash as delimiter.

```
cs7 instance 0
  point-code delimiter dash
  point-code 0-23-1
```

14.5 AS and ASP

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

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

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

For example:

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

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

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

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

To fix above config, link the asp to an as by adding asp my-asp:
14.6 Subsystem Number (SSN)

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

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

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

14.7 Routing Context / Routing Key

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

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

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

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

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

```
cs7 instance 0
point-code 1.23.3
as my-as m3ua
r Kent 2 0.23.1
```

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

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

14.7.1 M3UA without Routing Context IE / Routing Context 0

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

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

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

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

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

### 14.7.2 Example: Static Routing

Osmocom SS7 supports dynamic routing key registration via M3UA Routing Key Management (RKM), allowing minimal SS7 configuration. If all of your components support dynamic RKM, you should probably use it: see `accept-asp-connections dynamic-permitted` in osmo-stp.cfg.

This chapter explains how to configure osmo-stp if dynamic RKM is not an option.

In this example, let’s connect osmo-bsc via osmo-stp to osmo-msc using only static SS7 routing.

<table>
<thead>
<tr>
<th>BSC</th>
<th>STP</th>
<th>MSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP 1.1.1.1</td>
<td>IP 2.2.2.2</td>
<td>IP 3.3.3.3</td>
</tr>
<tr>
<td>M3UA 2905</td>
<td>M3UA 2905</td>
<td>M3UA 2905</td>
</tr>
<tr>
<td>PC 1.1.1</td>
<td>PC 3.3.3</td>
<td></td>
</tr>
</tbody>
</table>

Every one static route fanning out from STP gets assigned a distinct Routing Key — a simple integer number. Above, the BSC’s link has RK 1, the MSC’s link has RK 3.

For static routing, the M3UA port numbers must be fixed, i.e. there must be no 0 for a client’s local port as in `asp foo 2905 0 m3ua`. Instead, you may use `asp foo 2905 2905 m3ua`.

The BSC needs to configure:

- its own point-code — has to match the PC configured for the BSC in osmo-stp.cfg
- the routing key — has to match the RK assigned to BSC’s PC in osmo-stp.cfg
- the MSC’s point-code — has to match the PC in osmo-stp.cfg and osmo-msc.cfg
- local and remote IP:ports for M3UA — have to match the IP:ports in osmo-stp.cfg

The MSC needs to configure:

- its own point-code — has to match the PC configured for the MSC in osmo-stp.cfg
- the routing key — has to match the RK assigned to MSC’s PC in osmo-stp.cfg
- local and remote IP:ports for M3UA — have to match the IP:ports in osmo-stp.cfg

The STP needs to configure:

- all point-codes — they have to match the PCs in osmo-bsc.cfg and osmo-msc.cfg
- all routing keys — they have to match the RKs used in osmo-bsc.cfg and osmo-msc.cfg
- local and remote IP:ports for M3UA — have to match the IP:ports in osmo-bsc.cfg and osmo-msc.cfg

osmo-bsc.cfg
For comparison, the same setup with dynamic routing key management is a lot shorter, especially at osmo-stp.cfg, and there is no need to manually configure point-codes and routing keys between STP and {BSC,MSC}:

osmo-bsc.cfg

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15 Configure SCCP/M3UA

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

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

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

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

For example, in an all-Osmocom minimal setup,

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

• and the RESET ACK response from the MSC is routed back to the BSC’s point-code 1.23.3.

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

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

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

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

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

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

• A-interface: OsmoBSC to OsmoMSC

• IuCS-interface: OsmoHNBGW to OsmoMSC

• IuPS-interface: OsmoHNBGW to OsmoSGSN

• Lb-interface: OsmoSMLC to OsmoBSC

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

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

### 15.1 Connect to STP Instance

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

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

---

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Be aware that such an asp needs to be linked to an as, see Section 15.5.

By default, an STP instance is assumed to listen on the default M3UA port (2905) on the local host. That means in general 127.0.0.1 will be used as default remote SCTP address, and ::1 will be added to the SCTP association if IPv6 support is available on the system.

Note
OsmoSTP listens by default on :: if IPv6 is enabled on the system, and on 0.0.0.0 otherwise. Address :: actually superseeds 0.0.0.0, meaning it will listen on all IPv4 and IPv6 addresses available on the system.

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

15.2 Local Point-Code

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

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

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

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

See also Section 15.4.

15.3 Remote Point-Code

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

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

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

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

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

Examples:

- An OsmoBSC configures the MSC’s remote SCCP address:
An HNBGW configures both the remote MSC’s and SGSN’s SCCP addresses:

```plaintext
cs7 instance 0
  sccp-address my-remote-msc
  point-code 1.23.1
msc 0
  msc-addr my-remote-msc
```

Besides a point-code, an SCCP address can have several routing indicators:

- **PC**: routing by point-code is the default for Osmocom.
- **GT**: routing by Global Title is configurable by `routing-indicator GT`.
- **IP**: routing by IP address is configurable by `routing-indicator IP`.

In OsmoSTP, only routing by point-code is currently implemented.

### 15.4 Point-Code Format

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

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

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

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

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

It is also possible to use a dash as delimiter.

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

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

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

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

For example:

```bash
cs7 instance 0
asp my-as 2905 0 m3ua
  # where to reach the STP:
  remote-ip 127.0.0.1
  role asp
  sctp-role client
  as my-as 3ua
  asp my-as
```

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

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

```bash
cs7 instance 0
asp my-as 2905 0 m3ua
  remote-ip 127.0.0.1
  role asp
  sctp-role client
  as my-as 3ua
  routing-key 2 0.23.1
```

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

```bash
cs7 instance 0
asp my-as 2905 0 m3ua
  remote-ip 127.0.0.1
  role asp
  sctp-role client
  as my-as 3ua
  asp my-as
  routing-key 2 0.23.1
```

15.6 Subsystem Number (SSN)

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

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

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

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

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

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

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

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

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

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

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

15.7.1 M3UA without Routing Context IE / Routing Context 0

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

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

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

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

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

15.7.2 Example: Static Routing

Osmocom SS7 supports dynamic routing key registration via M3UA Routing Key Management (RKM), allowing minimal SS7 configuration. If all of your components support dynamic RKM, you should probably use it: see accept-asp-connections dynamic-permitted in osmo-stp.cfg.

This chapter explains how to configure osmo-stp if dynamic RKM is not an option.

In this example, let’s connect osmo-bsc via osmo-stp to osmo-msc using only static SS7 routing.

<table>
<thead>
<tr>
<th>BSC</th>
<th>&lt;--RK-1--&gt;</th>
<th>STP</th>
<th>&lt;--RK-3--&gt;</th>
<th>MSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP 1.1.1.1</td>
<td>IP 2.2.2.2</td>
<td>IP 3.3.3.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M3UA 2905</td>
<td>M3UA 2905</td>
<td>M3UA 2905</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC 1.1.1</td>
<td>PC 3.3.3</td>
<td>PC 3.3.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Every one static route fanning out from STP gets assigned a distinct Routing Key — a simple integer number. Above, the BSC’s link has RK 1, the MSC’s link has RK 3.

For static routing, the M3UA port numbers must be fixed, i.e. there must be no 0 for a client’s local port as in asp foo 2905 0 m3ua. Instead, you may use asp foo 2905 2905 m3ua.

The BSC needs to configure:

- its own point-code — has to match the PC configured for the BSC in osmo-stp.cfg
- the routing key — has to match the RK assigned to BSC’s PC in osmo-stp.cfg
- the MSC’s point-code — has to match the PC in osmo-stp.cfg and osmo-msc.cfg
- local and remote IP:ports for M3UA — have to match the IP:ports in osmo-stp.cfg

The MSC needs to configure:

- its own point-code — has to match the PC configured for the MSC in osmo-stp.cfg
- the routing key — has to match the RK assigned to MSC’s PC in osmo-stp.cfg
- local and remote IP:ports for M3UA — have to match the IP:ports in osmo-stp.cfg

The STP needs to configure:

- all point-codes — they have to match the PCs in osmo-bsc.cfg and osmo-msc.cfg
- all routing keys — they have to match the RKs used in osmo-bsc.cfg and osmo-msc.cfg
- local and remote IP:ports for M3UA — have to match the IP:ports in osmo-bsc.cfg and osmo-msc.cfg

**osmo-bsc.cfg**

```
cs7 instance 0
 point-code 1.1.1

asp mybsc-0 2905 2905 m3ua
 remote-ip 2.2.2.2
 local-ip 1.1.1.1
 sctp-role client
 as mybsc0 m3ua
 asp mybsc0-0
 routing-key 1 1.1.1

sccp-address mymsc
 routing-indicator PC
 point-code 3.3.3

msc 0
 msc-addr mymsc
```

**osmo-stp.cfg**

```
cs7 instance 0
 xua rkm routing-key-allocation static-only
 listen m3ua 2905
 accept-asp-connections pre-configured
 local-ip 2.2.2.2

# asp <name> <remote-port> <local-port|0> m3ua
asp mybsc-0 2905 2905 m3ua
remote-ip 1.1.1.1
```

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local-ip 2.2.2.2
as mybsc m3ua
asp bsc-0
routing-key 1 1.1.1
asp mymsc-0 2905 2905 m3ua
remote-ip 3.3.3.3
local-ip 2.2.2.2
as mymsc m3ua
asp mymsc-0
routing-key 3 3.3.3

route-table system
update route 1.1.1 7.255.7 linkset mybsc
update route 3.3.3 7.255.7 linkset mymsc

For comparison, the same setup with dynamic routing key management is a lot shorter, especially at osmo-stp.cfg, and there is
no need to manually configure point-codes and routing keys between STP and {BSC,MSC}:

osmo-bsc.cfg

cs7 instance 0
point-code 3.3.3
asp mybsc-0 2905 0 m3ua
remote-ip 2.2.2.2
local-ip 3.3.3.3
sctp-role client
as mybsc0 m3ua
asp mybsc0-0
routing-key 3 3.3.3

msc 0
msc-addr mymsc

sccp-address mymsc
routing-indicator PC
point-code 3.3.3

osmo-stp.cfg

cs7 instance 0
xua rkm routing-key-allocation dynamic-permitted
listen m3ua 2905
accept-asp-connections dynamic-permitted
local-ip 2.2.2.2

osmo-msc.cfg

16 Configuring the Core Network

The core network parameters are configured by the config file (as in `osmo-msc -c osmo-msc.cfg`). The config file is parsed by the VTY, which is also available via telnet in the running `osmo-msc` instance. Be aware that even though you may be able to change these parameters without restarting `osmo-msc`, some may not take immediate effect, and it is safest to use the config file to have these parameters set at startup time.

The core network parameters are found in the `config/network`.

A full reference to the available commands can be found in the OsmoMSC VTY reference manual [vty-ref-osmomsc]. This section describes only the most commonly used settings.

Here is an overview of the config items, described in more detail below:

```
network
country code 262
mobile network code 89
mm info 1
short name OsmoMSC
long name OsmoMSC
authentication required
encryption a5 3
```

**Tip**

Use the telnet VTY interface to query the current configuration of a running `osmo-msc` process:

```
$ telnet localhost 4254
OsmoMSC> enable
OsmoMSC# show running-config
```

Some parameters may be changed without restarting `osmo-msc`. To reach the network node, enter:

```
OsmoMSC> enable
OsmoMSC# configure terminal
OsmoMSC(config)# network
OsmoMSC(config-net)# short name Example-Name
OsmoMSC(config-net)# exit
OsmoMSC(config)#
```

The telnet VTY features tab-completion as well as context sensitive help shown when entering a `?` question mark. You can always use the `list VTY` command or enter `?` on the blank prompt to get a list of all possible commands at the current node.

16.1 MCC/MNC

The key identities of every GSM PLMN is the Mobile Country Code and the Mobile Network Code. They are identical over the entire network. In most cases, the MCC/MNC will be allocated to the operator by the respective local regulatory authority. For example, to set the MCC/MNC of 262-89, have this in your `osmo-msc.cfg`:
16.2 Configuring MM INFO

The MM INFO procedure can be used after a successful LOCATION UPDATE in order to transmit the human-readable network name as well as local time zone information to the MS. By default, MM INFO is not active, i.e. 0. Set to 1 to activate this feature:

```
network
network country code 262
mobile network code 89
```

**Note**
Not all phones support the MM INFO procedure. If a phone is not factory-programmed to contain the name for your MCC/MNC, it will likely only provide a numeric display of the network name, such as 262-89, or show the country code transformed into a letter, such as D 89.

The time information transmitted is determined by the local system time of the operating system on which OsmoMSC is running.

16.3 Authentication

A subscriber’s IMSI must be entered in the HLR database to be able to attach. A subscriber-create-on-demand feature is also available, see the OsmoHLR reference manual [userman-osmohlr].

A known IMSI in the HLR may or may not have authentication keys associated, which profoundly affects the ability to attach and the algorithms used to negotiate authentication, as the following sections explain for 2G and 3G.

16.3.1 Authentication on 2G

If authentication tokens (such as KI for 2G, or K and OP/OPC for UMTS) are present in the HLR, OsmoMSC will only attach a subscriber after successful authentication. Note that the 3G authentication keys are also used on 2G when the MS indicates UMTS AKA capability, in which case the full UMTS style mutual authentication may indeed take place on 2G (GERAN).

On 2G, if no authentication keys are present in the HLR for a given subscriber, OsmoMSC will attach the subscriber without authentication. Subscribers that lack authentication keys can always be rejected with this setting:

```
network
authentication required
```

16.3.2 Authentication on 3G

3G (UTRAN) always requires authentication (a.k.a. Integrity Protection) by specification, and hence authentication keys must be present in the HLR for a subscriber to be able to attach on 3G.

OsmoMSC always indicates UIA1 and UIA2 as permitted Integrity Protection algorithms on 3G.

16.4 Ciphering

To enable ciphering on the radio link, authentication must take place first: the Kc resulting from authentication is the key used for ciphering. Hence, to be able to use ciphering, a subscriber must have authentication tokens available in the HLR.
16.4.1 Ciphering on 2G

The MS, BTS and MSC must agree on a ciphering algorithm to use.

- The MS sends its supported ciphering algorithms via Classmark IEs during Location Updating.
- Typically the BSC needs to know which A5 ciphers are supported by connected BTSes, see the network / encryption a5 configuration item for OsmoBSC [vty-ref-osmobsc].
- Finally, OsmoMSC may impose that specific A5 ciphers shall not be considered.

It is the responsibility of the BSC to then pick an A5 cipher that satisfies all requirements.

- In OsmoMSC, A5/0 means that ciphering is turned off.

```
network
   encryption a5 0
```

- A5/1 and A5/3 are currently supported by Osmocom.

```
network
   encryption a5 1 3
```

- Never use A5/2: it is an "export grade cipher" and has been deprecated for its low ciphering strength.
- To allow either no encryption or any of A5/1 or A5/3 based on the presence of authentication keys and abilities of the MS, SIM and BSC configuration, it is recommended to enable all ciphers in OsmoMSC. The highest available A5 cipher will be used; the order in which the A5 options are configured does not affect the choice.

```
network
   encryption a5 0 1 3
```

16.4.2 Ciphering on 3G

While authentication is always required on 3G, ciphering is optional.

So far OsmoMSC allows switching ciphering on 3G either on or off — the default behavior is to enable ciphering. (Individual choice of algorithms may be added in the future.)

Disable 3G ciphering:

```
network
   encryption uea 0
```

Enable 3G ciphering (default):

```
network
   encryption uea 1 2
```

OsmoMSC indicates UEA1 and UEA2 as permitted encryption algorithms on 3G.
17 Short Message Peer to Peer (SMPP)

The Short Message Peer to Peer (SMPP) Protocol [smpp-34] has been used for the communication with SMSCs. Osmocom implements version 3.4 of the protocol. Using this interface one can send MT-SMS to an attached subscriber or receive unrouted MO-SMS.

SMPP is served by the Osmocom MSC layer (both in the old OsmoNITB as well as the new OsmoMSC.

SMPP describes a situation where multiple ESMEs (External SMS Entities) interact with a SMSC (SMS Service Center) via the SMPP protocol. Each entity is identified by its System Id. The System ID is a character string which is configured by the system administrator.

OsmoMSC implements the SMSC side of SMPP and subsequently acts as a TCP server accepting incoming connections from ESME client programs.

Each ESME identifies itself to the SMSC with its system-id and an optional shared password.

17.1 Global SMPP configuration

There is a smpp vty node at the top level of the OsmoMSC configuration. Under this node, the global SMPP configuration is performed.

Use the local-tcp-ip command to define the TCP IP and port at which the OsmoMSC internal SMSC should listen for incoming SMPP connections. The default behaviour is to listen on all IPs (0.0.0.0), and the default port assigned to SMPP is 2775.

Use the system-id command to define the System ID of the SMSC.

Use the policy parameter to define whether only explicitly configured ESMEs are permitted to access the SMSC (closed), or whether any ESME should be accepted (accept-all).

Use the smpp-first command to define if SMPP routes have higher precedence than MSISDNs contained in the HLR (smpp-first), or if only MSISDNs found not in the HLR should be considered for routing to SMPP (no smpp-first).

17.2 ESME configuration

Under the smpp vty node, you can add any number of esme nodes, one for each ESME that you wish to configure.

Use the esme NAME command (where NAME corresponds to the system-id of the ESME to be configured) under the SMPP vty node to enter the configuration node for this given ESME.

Use the password command to specify the password (if any) for the ESME.

Use the default-route command to indicate that any MO-SMS without a more specific route should be routed to this ESME.

Use the deliver-src-imsi command to indicate that the SMPP DELIVER messages for MO SMS and the SMPP ALERT should state the IMSI (rather than the MSISDN) as source address.

Use the osmocom-extensions command to request that Osmocom specific extension TLVs shall be included in the SMPP PDUs. Those extensions include the ARFCN of the cell, the L1 transmit power of the MS, the timing advance, the uplink and downlink RxLev and RxQual, as well as the IMEI of the terminal at the time of generating the SMPP DELIVER PDU.

Use the dcs-transparent command to transparently pass the DCS value from the SMS Layer3 protocols to SMPP, instead of converting them to the SMPP-specific values.

Use the route prefix command to specify a route towards this ESME. Using routes, you specify which destination MSISDNs should be routed towards your ESME.
17.3 Example configuration snippet

The following example configuration snippet shows a single ESME *galactica* with a prefix-route of all national numbers stating with 2342:

```
smpp
  local-tcp-port 2775
  policy closed
  no smpp-first
  esme galactica
  password SoSayWeAll
  deliver-src-imsi
  osmocom-extensions
  route prefix national isdn 2342
```

17.4 Osmocom SMPP protocol extensions

Osmocom has implemented some extensions to the SMPP v3.4 protocol.

These extensions can be enabled using the `osmocom-extensions` VTY command at `esme` level.

The TLV definitions can be found in the `<osmocom/gsm/protocol/smpp34_osmocom.h>` header file provided by libosmocore.

17.4.1 RF channel measurements

When the Osmocom SMPP extensions are enabled, we add the following TLVs to each SMPP DELIVER PDU:

<table>
<thead>
<tr>
<th>TLV</th>
<th>IEI</th>
<th>Length (Octets)</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLVID_osmo_arfcn</td>
<td>0x2300</td>
<td>2</td>
<td>GSM ARFCN of the radio interface</td>
</tr>
<tr>
<td>TLVID_osmo_ta</td>
<td>0x2301</td>
<td>1</td>
<td>Timing Advance on the radio interface</td>
</tr>
<tr>
<td>TLVID_osmo_ms_l1_txpwr</td>
<td>0x2307</td>
<td>1</td>
<td>Transmit Power of the MS in uplink direction</td>
</tr>
<tr>
<td>TLVID_osmo_rxlev_ul</td>
<td>0x2302</td>
<td>2</td>
<td>Uplink receive level as measured by BTS in dBm (int16_t)</td>
</tr>
<tr>
<td>TLVID_osmo_rxqual_ul</td>
<td>0x2303</td>
<td>1</td>
<td>Uplink RxQual value as measured by BTS</td>
</tr>
<tr>
<td>TLVID_osmo_rxlev_dl</td>
<td>0x2304</td>
<td>2</td>
<td>Downlink receive level as measured by MS in dBm (int16_t)</td>
</tr>
<tr>
<td>TLVID_osmo_rxqual_dl</td>
<td>0x2305</td>
<td>1</td>
<td>Downlink RxQual value as measured by MS</td>
</tr>
</tbody>
</table>

All of the above values reflect the last measurement report as received via A-bis RSL from the BTS. It is thus a snapshot value (of the average within one 480ms SACCH period), and not an average over all the SACCH periods during which the channel was open or the SMS was received. Not all measurement reports contain all the values. So you might not get an TLVID_osmo_rxlev_dl IE, as that particular uplink frame might have been lost for the given snapshot we report.

17.4.2 Equipment IMEI

If we know the IMEI of the subscriber’s phone, we add the following TLV to each SMPP DELIVER PDU:

<table>
<thead>
<tr>
<th>TLV</th>
<th>IEI</th>
<th>Length</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLVID_osmo_imei</td>
<td>0x2306</td>
<td>variable</td>
<td>IMEI of the subscriber’s phone (ME)</td>
</tr>
</tbody>
</table>
18 MNCC for External Call Control

The 3GPP GSM specifications define an interface point (service access point) inside the MSC between the call-control part and the rest of the system. This service access point is called the MNCC-SAP. It is described in 3GPP TS 24.007 [3gpp-ts-24-007] Chapter 7.1.

However, like for all internal interfaces, 3GPP does not give any specific encoding for the primitives passed at this SAP.

The MNCC protocol has been created by the Osmocom community and allows to control the call handling and audio processing by an external application. The interface is currently exposed using Unix Domain Sockets. The protocol is defined in the `mncc.h` header file.

It is exposed by the Osmocom MSC layer (both in the old OsmoNITB as well as the new OsmoMSC).

OsmoMSC can run in two different modes:

1. with internal MNCC handler
2. with external MNCC handler

### 18.1 Internal MNCC handler

When the internal MNCC handler is enabled, OsmoMSC will switch voice calls between GSM subscribers internally and automatically based on the the subscribers extension number. No external software is required.

**Note**

Internal MNCC is the default behavior.

### 18.1.1 Internal MNCC Configuration

The internal MNCC handler offers some configuration parameters under the `mncc-int` VTY configuration node.

#### 18.1.1.1 default-codec tch-f (fr|efr|amr)

Using this command, you can configure the default voice codec to be used by voice calls on TCH/F channels.

#### 18.1.1.2 default-codec tch-h (hr|amr)

Using this command, you can configure the default voice codec to be used by voice calls on TCH/H channels.

### 18.2 External MNCC handler

When the external MNCC handler is enabled, OsmoMSC will not perform any internal call switching, but delegate all call-control handling towards the external MNCC program connected via the MNCC socket.

If you intend to operate OsmoMSC with external MNCC handler, you have to disable the internal MNCC handler and specify the MNCC socket path in the configuration file.

At the time of this writing, there are only two known open source applications implementing the MNCC interface compatible with the Osmocom MNCC socket:

- historically `lcr`, the Linux Call Router (support for modern MNCC protocol versions may be missing)
- `osmo-sip-connector`, the more up-to-date integration of external call routing by translating MNCC into a SIP trunk towards an external SIP PBX / switch.
18.3 DTMF considerations

In mobile networks, the signaling of DTMF tones is implemented differently, depending on the signaling direction. A mobile originated DTMF tone is signaled using START/STOP DTMF messages which are hauled through various protocols upwards into the core network.

Contrary to that, a mobile terminated DTMF tone is not transferred as an out of band message. Instead, in-band signaling is used, which means a tone is injected early inside a PBX or MGW.

When using OsmoMSC with its built in MNCC functionality a mobile originated DTMF message will not be translated into an in-band tone. Therefore, sending DTMF will not work when internal MNCC is used.

For external MNCC, the network integrator must make sure that the back-end components are configured properly in order to handle the two different signaling schemes depending on the signaling direction.

Note

osmo-sip-connector will translate MNCC DTMF signaling into sip-info messages. DTMF signaling in the opposite direction is not possible. osmo-sip-connector will reject sip-info messages that attempt to signal a DTMF tone.

18.4 MNCC protocol description

The protocol follows the primitives specified in 3GPP TS 04.07 Chapter 7.1. The encoding of the primitives is provided in the mncc.h header file in OsmoMSC’s source tree, which uses some common definitions from osmocom/gsm/mncc.h (part of libosmocore.git).

However, Osmocom’s MNCC specifies a number of additional primitives beyond those listed in the 3GPP specification.

The different calls in the network are distinguished by their callref (call reference), which is a unique unsigned 32bit integer.

18.4.1 MNCC_HOLD_IND

Direction: OsmoMSC → Handler
A CC HOLD message was received from the MS.

18.4.2 MNCC_HOLD_CNF

Direction: Handler → OsmoMSC
Acknowledge a previously-received CC HOLD message, causes the transmission of a CC HOLD ACK message to the MS.

18.4.3 MNCC_HOLD_REJ

Direction: Handler → OsmoMSC
Reject a previously-received CC HOLD message, causes the transmission of a CC HOLD REJ message to the MS.

18.4.4 MNCC_RETRIEVE_IND

Direction: OsmoMSC → Handler
A CC RETRIEVE message was received from the MS.

18.4.5 MNCC_RETRIEVE_CNF

Direction: Handler → OsmoMSC
Acknowledge a previously-received CC RETRIEVE message, causes the transmission of a CC RETRIEVE ACK message to the MS.
18.4.6 MNCC_RETRIEVE_REJ
Direction: Handler → OsmoMSC
Reject a previously-received CC RETRIEVE message, causes the transmission of a CC RETRIEVE REJ message to the MS.

18.4.7 MNCC_USERINFO_REQ
Direction: OsmoMSC → Handler
Causes a CC USER INFO message to be sent to the MS.

18.4.8 MNCC_USERINFO_IND
Direction: OsmoMSC → Handler
Indicates that a CC USER-USER message has been received from the MS.

18.4.9 MNCC_BRIDGE
Direction: Handler → OsmoMSC
Requests that the TCH (voice) channels of two calls shall be inter-connected. This is the old-fashioned way of using MNCC, historically required for circuit-switched BTSs whose TRAU frames are received via an E1 interface card, and works only when the TCH channel types match.

Note
Internal MNCC uses MNCC_BRIDGE to connect calls directly between connected BTSs or RNCs, in effect disallowing calls between mismatching TCH types and forcing all BTSs to be configured with exactly one TCH type and codec. This is a limitation that will probably remain for the old OsmoNITB. For the new OsmoMSC, the MNCC_BRIDGE command will instruct the separate OsmoMGW to bridge calls, which will be able to handle transcoding between different TCH as well as 3G (IuUP) payloads (but note: not yet implemented at the time of writing this). Hence an external MNCC may decide to bridge calls directly between BTSs or RNCs that both are internal to the OsmoMSC, for optimization reasons.

18.4.10 MNCC_FRAME_RECV
Direction: Handler → OsmoMSC
Enable the forwarding of TCH voice frames via the MNCC interface in OsmoMSC→Handler direction for the specified call.

18.4.11 MNCC_FRAME_DROP
Direction: Handler → OsmoMSC
Disable the forwarding of TCH voice frames via the MNCC interface in OsmoMSC→Handler direction for the specified call.

18.4.12 MNCC_LCHAN_MODIFY
Direction: Handler → OsmoMSC
Modify the current dedicated radio channel from signalling to voice, or if it is a signalling-only channel (SDCCH), assign a TCH to the MS.
18.4.13 **MNCC_RTP_CREATE**

**Direction:** Handler → OsmoMSC

Create a RTP socket for this call at the BTS/TRAU that serves this BTS.

18.4.14 **MNCC_RTP_CONNECT**

**Direction:** Handler → OsmoMSC

Connect the RTP socket of this call to the given remote IP address and port.

18.4.15 **MNCC_RTP_FREE**

**Direction:** Handler → OsmoMSC

Release a RTP connection for one given call.

18.4.16 **GSM_TCHF_FRAME**

**Direction:** both

Transfer the payload of a GSM Full-Rate (FR) voice frame between the OsmoMSC and an external MNCC handler.

18.4.17 **GSM_TCHF_FRAME_EFR**

**Direction:** both

Transfer the payload of a GSM Enhanced Full-Rate (EFR) voice frame between the OsmoMSC and an external MNCC handler.

18.4.18 **GSM_TCHH_FRAME**

**Direction:** both

Transfer the payload of a GSM Half-Rate (HR) voice frame between the OsmoMSC and an external MNCC handler.

18.4.19 **GSM_TCH_FRAE_AMR**

**Direction:** both

Transfer the payload of a GSM Adaptive-Multi-Rate (AMR) voice frame between the OsmoMSC and an external MNCC handler.

18.4.20 **GSM_BAD_FRAME**

**Direction:** OsmoMSC → Handler

Indicate that no valid voice frame, but a bad frame was received over the radio link from the MS.

18.4.21 **MNCC_START_DTMF_IND**

**Direction:** OsmoMSC → Handler

Indicate the beginning of a DTMF tone playback.
18.4.22 MNCC_START_DTMF_RSP

Direction: Handler → OsmoMSC
Acknowledge that the DTMF tone playback has been started.

18.4.23 MNCC_START_DTMF_REJ

Direction: both
Indicate that starting a DTMF tone playback was not possible.

18.4.24 MNCC_STOP_DTMF_IND

Direction: OsmoMSC → Handler
Indicate the ending of a DTMF tone playback.

18.4.25 MNCC_STOP_DTMF_RSP

Direction: Handler → OsmoMSC
Acknowledge that the DTMF tone playback has been stopped.

19 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.

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).

19.1 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 \texttt{osmux peer-behind-nat (on|off)} VTY commands.

If OsmoMGW itself is behind a NAT, it must use the VTY config \texttt{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 \texttt{rtp keep-alive} configured with the \texttt{<1-120>} value in order to force transmission of dummy packets every few seconds.

Osmux implementations such as OsmoMGW also come with the \texttt{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).

### 19.2 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.

\[
\begin{align*}
\text{BSC/MGW(localCID=Y,remoteCID=?)} & \leftarrow \text{X} \rightarrow \text{MSC/MGW(localCID=X,remoteCID=?)} \\
\text{BSC/MGW(localCID=Y,remoteCID=X)} & \rightarrow \text{Y} \rightarrow \text{MSC/MGW(localCID=X,remoteCID=Y)}
\end{align*}
\]

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.

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 \texttt{<localIPaddr, localPort>} tuple, allowing for 256 Osmux CID\texttt{s} 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 \texttt{<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 \texttt{<remoteIP, remotePort>} tuples and have an entire 256 Osmux CID space per \texttt{<remoteIP, remotePort>} (aka per peer).
19.3 3GPP AoIP network setup with Osmux

![Diagram of 3GPP AoIP network setup with Osmux]

Figure 5: Sample node diagram of a 3GPP AoIP network with Osmux enabled
We assume a SDCCH is already established

DTAP CM Service Request

Complete Layer 3 Information DTAP CM Service Request

MGCP CRCX rtpbridge/*mgw, X-Osmux: *

Bind to MGW-local Osmux Port (1984)
Allocate new endpoint 1, MGW’s local CID 5

MGCP CRCX rtpbridge/1@mgw OK (MGW:1984, X-Osmux: 5)

BSSAP ASSIGN REQ (3GPP AoIP, extension IE: Osmux CID 5)

RSL CHAN ACT

Assignment Command

Assignment Complete

IPA CRCX

Bind to BTS-local RTP Port (1000)

IPA CRCX ACK (BTS:1000)

IPA MDCX (MGW:2000)

Connect to BTS:1000

MGCP CRCX rtpbridge/2@mgw OK (MGW:1984, X-Osmux: 5)

IPA MDCX ACK

Connect RTP socket to remote MGW’s RTP Port

MGCP CRCX (MGW:2000)

MGCP CRCX rtpbridge/2@mgw (MGW:1985, X-Osmux: 7)

Connect remote Osmux to MGW addr from ASSGN CMPL

RTP Audio BTS:1000 MGW:2000

Um Audio (bidirectional)

DTAP CC ALERTING

Figure 6: MO-call with Osmux enable on 3GPP AoIP
19.4 SCCPLite network setup with Osmux

Figure 7: Sample node diagram of a 3GPP AoIP using A/IP with IPA/SCCPlite network with Osmux enabled
We assume a SDCCH is already established

DTAP CM Service Request

Complete Layer 3 Information DTAP CM Service Request

Connection Confirmed

MGCP CRCX 1@mgw, X-Osmux: *

Bind to MGW-local Osmux Port

MGCP CRCX 1@mgw, X-Osmux: *

Allocate new endpoint 1, MGW's local CID 5

MGCP CRCX 1@mgw OK (MGW:1984, X-Osmux: 5)

BSSAP ASSGN REQ (CIC:1)

MGCP CRCX 1@mgw, X-Osmux: *

Bind to BTS-local RTP Port (1000)

MGCP CRCX 1@mgw OK (BTS:1000)

IPA CRCX

 IPA CRCX ACK (BTS:1000)

IPA MDCX (MGW:2000)

MGCP CRCX 1@mgw (BTS:1000)

MGCP CRCX 1@mgw OK (MGW:2000)

IPA MDCX (MGW:2000)

IPA MDCX ACK

BSSMAP ASSGN Complete

MGCP CRCX 1@mgw (MSC:1984, X-Osmux: 5)

Bind to BTS local Osmux Port (1000)

MGCP CRCX 1@mgw OK (MSC:1984, X-Osmux: 5)

MGCP MDCX 1@mgw (recvonly)

Connect Osmux socket to remote (MSC) Osmux Port

MGCP MDCX 1@mgw OK


RTP Audio BTS:1000 MGW:2000

Um Audio (unidirectional)

DTAP CC ALERTING

MGCP MDCX 1@mgw (sndrecv)

Switch to bi-directional audio

MGCP MDCX 1@mgw OK


RTP Audio BTS:1000 MGW:2000

Um Audio (bidirectional)

Figure 8: MO-call with Osmux enable on 3GPP AoIP using A/IP with IPA/SCCPlite
19.5 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
We assume a SDCCH is already established

DTAP CM Service Request

Complete Layer 3 Information DTAP CM Service Request

Connection Confirmed

MGCP CRCX rtpbridge/1@mgw OK (MGW:3000)

Bind to MGW-local RTP Port (3000)
Allocate new endpoint 1

MGCP CRCX 1@mgw OK (MGW:3000)

Bind to MGW-local RTP Port (3000)
Connect to BTS:1000

IPA CRCX ACK (BTS:1000)

MGCP CRCX 1@mgw (BTS:1000)

Bind to BTS-local RTP Port (1000)

IPA CRCX ACK (BTS:1000)

MGCP CRCX 1@mgw OK (MGW:2000)

Bind to MGW-local RTP Port (2000)
Connect to BTS:1000

IPA MDCX (MGW:2000)

MGCP CRCX 1@mgw (MGW:2000)

Bind to MGW-local RTP Port (2000)
Connect to BTS:1000

IPA MDCX ACK

MGCP CRCX 1@mgw OK (MGW:3000)

Allocate new endpoint 2
Allocate MGW's local CID 5

MGCP CRCX 2@mgw (MSC:1984, X-Osmux: 5)

Bind to local Osmux Port (1984)
Bind to local RTP port 4000

MGCP CRCX 2@mgw OK (MGW:1985, X-Osmux: 7)

MGCP CRCX 1@mgw OK (MGW:4000)

MGCP MDCX 1@mgw (recvonly)

Connect Osmux socket to remote (MGW) Osmux Port

MGCP MDCX 1@mgw OK

MGCP MDCX 2@mgw (recvonly)

Connect Osmux socket to remote (MSC) Osmux Port

MGCP MDCX 2@mgw OK

RTP Audio BSCNAT:4000 MGW:3000


Um Audio (unidirectional)

RTP Audio BTS: 1000 MGW:2000

DTAP CC ALERTING

MGCP MDCX 1@mgw (sndrecv)

Switch to bi-directional audio

MGCP MDCX 2@mgw (sndrecv)

MGCP MDCX 2@mgw OK

MGCP MDCX 1@mgw OK

RTP Audio BSCNAT:4000 MGW:3000


Um Audio (bidirectional)

RTP Audio BTS: 1000 MGW:2000

Figure 10: MO-call with Osmux enable on 3GPP AoIP using A/IP with IPA/SCCP-lite with a BSC-NAT between BSC and MSC
19.6 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.

19.6.1 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: *

19.6.2 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 asterisk (*) 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

<table>
<thead>
<tr>
<th>CRCX 189 rtpbridge/1@mgw MGCP 1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>C: 36</td>
</tr>
<tr>
<td>M: sendrecv</td>
</tr>
<tr>
<td>X-Osmux: 2</td>
</tr>
<tr>
<td>v=0</td>
</tr>
<tr>
<td>o=- 36 23 IN IP4 172.18.2.20</td>
</tr>
<tr>
<td>s=-</td>
</tr>
<tr>
<td>c=IN IP4 1.2.3.4</td>
</tr>
<tr>
<td>t=0 0</td>
</tr>
<tr>
<td>m=audio 2342 RTP/AVP 112</td>
</tr>
<tr>
<td>a=fmtp:112</td>
</tr>
<tr>
<td>a=rtpmap:112 AMR/8000/1</td>
</tr>
<tr>
<td>a=ptime:20</td>
</tr>
</tbody>
</table>

Example: response to CRCX containing the MGW’s local CID
19.6.3 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

```yaml
mgcp
...
  osmux on
  osmux bind-ip 172.18.1.20
  osmux port 1984
  osmux batch-factor 4
  osmux dummy on
```

1. Allow clients to set allocate Osmux connections in rtpbridge endpoints, while still allowing RTP connections
2. Bind the Osmux socket to the provided IP address
3. Bind the Osmux socket to the provided UDP port
4. Batch up to 4 RTP payloads of the same stream on each Osmux frame
5. Periodically send Osmux dummy frames, useful to punch a hole in NATs and maintain connections opened.

19.7 Abis setup with Osmux

![Sample node diagram of Osmux enabled in the Abis interface](image)

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

19.8.1 OsmoMSC in a A/IP with IPA/SCCPlite network setup

In this kind of setup, the CN side of BSC co-located MGW is managed by the MSC, meaning the use of Osmux is transparent to BSC since MSC takes care of both peer MGW connections. Moreover, in this case the MSC has no dynamic information on Osmux support in the BSC co-located MGW until CRCX time, which means configuration on both nodes need to be carefully set up so they can work together.

Osmux usage in OsmoMSC in managed through the VTY command `osmux (on|off|only)`. Since there’s no dynamic information on Osmux support, it may be required in the future to have an extra VTY command which can be set per BSC to fine-tune which ones should use Osmux and which shouldn’t.
OsmoMSC will behave differently during call set up based on the VTY command presented above:

- **off**: OsmoMSC won’t include an `X-Osmux` extension to CRCX sent to the BSC co-located MGW when configuring the CN side of the MGW endpoint. If the MGW answers with a CRCX ACK containing an `X-Osmux`, OsmoMSC will cancel the call establishment.

- **on**: OsmoMSC will initially configure its co-located MGW to use Osmux, then similarly send a CRCX with an `X-Osmux` extension towards the BSC co-located MGW. Under this configuration, if the BSC co-located MGW didn’t support Osmux, it could send a CRCX ACK without `X-Osmux` extension or fail (depending on its own configuration), and OsmoMSC could choose to re-create its local connection as non-Osmux (RTP) (and possibly try again against BSC co-located MGW), but this behavior is currently not implemented. As a result, currently `on` behaves the same as `only`.

- **only**: OsmoMSC will configure its co-located MGW as well as the BSC co-located MGW to use Osmux by including the `X-Osmux` MGCP extension. If MGW rejects to use Osmux, OsmoMSC will reject the call and the call establishment will fail.

### 19.8.2 OsmoMSC in a 3GPP AoIP network setup

Osmux usage in OsmoMSC in managed through the VTY command `osmux (on|off|only)`. Once enabled (`on` or `only`), OsmoMSC will start appending the vendor specific `Osmux Support` IE in BSSMAP RESET and BSSMAP RESET-ACK message towards the BSC in order to announce it supports Osmux, and BSC will do the same. This way, OsmoMSC can decide whether to use Osmux or not based on this information when setting up a call (this time using `Osmux CID` IE). It should be noted that this option should not be enabled unless BSCs managed by OsmoMSC support handling this extension IE (like OsmoBSC), 3rd-party BSCs might otherwise refuse the related `RESET/RESET-ACK` messages.

OsmoMSC will behave differently during call set up based on the VTY command presented above:

- **off**: OsmoMSC won’t use Osmux. That is, it will send a BSSMAP Assign Request without the `Osmux CID` IE, and will send a CRCX without `X-Osmux` extension towards its co-located MGW.

- **on**: If BSC announced Osmux support to OsmoMSC during BSSMAP RESET time, then OsmoMSC will set up the call to use Osmux (by adding `X-Osmux` to MGCP CRCX and `Osmux CID` IE to BSSMAP Assign Request). If the BSC didn’t announce Osmux support to OsmoMSC, then OsmoMSC will use RTP to set up the call (by avoiding addition of previously described bits).

- **only**: Same as per `on`, except that OsmoMSC will allow to set up only Osmux calls on the CN-side, this is, it will reject to set up voice calls for BSC which didn’t announce Osmux support.

### 20 MGW Pooling

OsmoMSC is able to use a pool of media gateway (MGW) instances. The aim of MGW pooling is to evenly distribute the RTP voice stream load across multiple MGW instances. This can help to scale out over multiple VMs or physical machines. Until osmo-mgw includes multithreading support, it may also be used to scale-out to multiple cores on a single host.

The load distribution is managed in such a way that when a new call is placed, the pool will automatically assign the call to the available MGW with the lowest load.

MGW pooling is recommended for larger RAN or CN installations. For small networks and lab installations the classic method with one MGW per OsmoMSC offers sufficient performance.

#### 20.1 MGW pool VTY configuration

In OsmoMSC the MGW is controlled via an MGCP-Client. The VTY commands to configure the MGCP-Client are part of the several `mgw` nodes, one per MGCP-Client to set up.

To setup an MGW pool, the user must first install multiple OsmoMGW instances, so that they won’t interfere with each other. This can be done using different local host IP addresses or different ports. When OsmoMGW is installed from packages, the systemd configuration may also require adjustment.
By default, MGCP-Client will use whatever source IP address is resolved by the kernel routing subsystem, and will also ask the
kernel to pick a free UDP port.

Example configuration with two MGCP-Client instances in a pool:

```plaintext
mgw 0
description media-gw-0
remote-ip 127.0.0.1
remote-port 2432
local-ip 127.0.0.1
local-port 2431
description media-gw-0
mgw 1
description media-gw-1
remote-ip 127.0.0.1
remote-port 2430
local-ip 127.0.0.1
local-port 2429
description media-gw-1
```

1, 2 When working with multiple MGW / MGCP-Client instances, the domain name for each MGW should be different. Otherwise it won’t be possible to distinguish the endpoint names in the log. It should also be noted that the domain name must match the configuration of the related OsmoMGW instance.

1, 2 It is also possible to assign a descriptive name to each MGW instance. The MGCP client specific log lines will then use this name as logging context. If no description is set, the domain name will be used.

### 20.2 MGW pool management

The MGW pool is fully runtime-manageable. The only limitation is that an MGCP-Client can not be restarted or removed as long as it is serving calls (see also: Section 20.2.5).

#### 20.2.1 MGW pool status

The VTY implements a `show mgw-pool` command that lists the currently configured MGW pool members, their status and call utilization. The following snippet shows an output example run on OsmoBSC, but it should be also available on other applications supporting the MGW pooling VTY features:

```
OsmoBSC> show mgw-pool
% MGW-Pool:
% MGW 0:media-gw-0
% MGCP link: connected,UP
% service: unblocked
% ongoing calls: 1
% MGW 1:media-gw-1
% MGCP link: connected,UP
% service: unblocked
% ongoing calls: 0
```

#### 20.2.2 Adding an MGW / MGCP-Client to the MGW pool

To add a new MGCP-Client to the pool, the `mgw` node is used. Like with the `bts` or the `msc` node a reference number is used that usually starts at 0. However it is still possible to assign any number from 0-255. The enumeration also may contain gaps. The following snippet shows an output example run on OsmoBSC, but it should be also available on other applications supporting the MGW pooling VTY features:
OsmoMSC> enable
OsmoMSC# configure terminal
OsmoMSC(config)# network
OsmoMSC(config-net)# mgw 2
OsmoMSC(config-mgw)# ?
keepalive Monitor if the MGCP link against MGW is still usable
local-ip local bind to connect to MGW from
local-port local port to connect to MGW from
remote-ip remote IP address to reach the MGW at
remote-port remote port to reach the MGW at
endpoint-domain Set the domain name to send in MGCP messages, e.g. the part 'foo' in '← rtpbridge/*@foo'.
reset-endpoint Add an endpoint name that should be reset (DLCX) on connect to the reset ← -endpoint list, e.g. 'rtpbridge/*'

The newly added MGW will immediately appear in the mgw-pool list but it won’t be used until its configuration finished by reconnecting it.

% MGW-Pool:
% MGW 0:media-gw-0
% MGCP link:  connected,UP
% service:  unblocked
% ongoing calls: 2
% MGW 1:media-gw-1
% MGCP link:  connected,UP
% service:  unblocked
% ongoing calls: 3
% MGW 2:mgw
% MGCP link:  disconnected,DOWN
% service:  unblocked
% ongoing calls: 0

íst example a description is not set yet, so the domain name ("mgw") is displayed.

### 20.2.3 Reconnecting an MGW / MGCP-Client

It may become necessary to reconnect an MGCP-Client. This is the case when the VTY configuration was changed at runtime. In order to make the changes effective the MGW configuration must be reloaded by reconnecting the MGW connection. Also newly created MGW instances require a reconnect once their configuration is done.

To reconnect an MGCP-Client use the *reconnect* VTY command:

OsmoMSC# mgw 2 reconnect

The mgcp-client status should immediately change to *connected*. The MGW is now ready to be used for new calls.

OsmoMSC# show mgw-pool
% MGW-Pool:
% MGW 0:media-gw-0
% MGCP link:  connected,UP
% service:  unblocked
% ongoing calls: 2
% MGW 1:media-gw-1
% MGCP link:  connected,UP
% service:  unblocked
% ongoing calls: 3
% MGW 2:mgw
% MGCP link:  connected,UP
% service:  unblocked
% ongoing calls: 0
It should be noted that MGCP a protocol is used via UDP, the connect only happens locally to forward the UDP datagrams properly (state printed in mgcp-client: (dis)connected above). Also (unless a reset endpoint is configured like in the example config above) there will be no immediate interaction with the MGW. However, the log should at least confirm the connect worked and the MGCP client has been created successfully.

Mon Aug 2 17:15:00 2021 DLMGCP mgcp_client.c:788 MGCP client: using endpoint domain '@mgw'
Mon Aug 2 17:15:00 2021 DLMGCP mgcp_client.c:908 MGCP GW connection: r=127.0.0.1:2427<->l ← 127.0.0.1:2727

For that reason, it is strongly advised to enable the keepalive feature in OsmoMSC to schedule periodical MGCP queries against the MGW, in order to make sure it is reachable (the state MGCP link: UP|DOWN printed above). See section Section 20.2.4 below for more information.

20.2.4 Monitor MGCP link (keepalive) / MGCP-Client

The keepalive feature in OsmoMSC allows scheduling periodical queries on the MGCP layer in order to make sure it is reachable and hence obtain information on the state of the MGCP link. This is in turn used by the MGW Pool when picking an MGW from the pool: MGWs whose link is considered to be DOWN are skipped.

The feature consists of: - A keepalive request-interval which will trigger a transmission of an MGCP AuditEndpoint command targeting endpoint with name keepalive request-endpoint. This interval is updated every time any message is transmitted in the MGCP link, meaning the MGCP AuditEndpoint message is only triggered if no message has been transmitted since keepalive request-interval seconds ago. - A keepalive timeout which upon triggering (because no message was received over that amount of time) will then consider the MGW to be non-reachable (link DOWN).

The keepalive parameters are to be preferrably configured so that "keepalive request-interval" * 2 < "keepalive timeout".

Example VTY configuration of keepalive feature in OsmoMSC:

```
mgw 0
...  
keepalive request-interval 20
keepalive request-endpoint null
keepalive timeout 50
```

1. Transmit an MGCP AuditEndpoint message to the MGW if no message has been sent to it over last 20 seconds
2. The MGCP AuditEndpoint targets the null endpoint. This is a special endpoint available at OsmoMGW for those purposes, but any available endpoint can be configured and used instead.
3. Consider the MGCP link to be DOWN if no message is received from the MGW over the last 50 seconds

**Note**
The keepalive feature is disabled by default, and must be explicitly configured in order to enable it.

20.2.5 Blocking an MGW / MGCP-Client

If it becomes apparent that an MGCP-Client must be restarted or removed from the config (maintenance) the operator can put that MGCP-Client into a blocked mode. A blocked MGCP-Client will still serve the ongoing calls but it will not be picked for the assignment of new calls.

To block an MGCP-Client use the block VTY command:

```
OsmoBSC# mgw 2 block
OsmoBSC# show mgw-pool
% MGW-Pool:
% MGW 0:media-gw-0
```
When the number of ongoing calls has tapered off, the MGW / MGCP-Client can be restarted or removed if necessary.

If the blockade should be reverted, the `unblock` VTY command can be used in the same way to remove the blockade. (Reconnecting will not remove the blockade.)

### 20.2.6 Removing an MGW / MGCP-Client

An MGCP-Client is removed from the pool using the `no mgw` command from the configure terminal. The MGCP-Client instance will automatically be terminated and the related resources are freed. The only requirement is that there are no ongoing calls on the selected instance.

```
OsmoBSC# configure terminal
OsmoBSC(config)# network
OsmoBSC(config-net)# no mgw 2
```

### 21 SGs interface

OsmoMSC offers an SGs interface using the SGsAP protocol. The SGs interface is an optional interface between a 2G (GERAN) / 3G (UTRAN) MSC and an 4G (EUTRAN) MME. Its purpose is to facilitate both CSFB (Circuit-Switched Fall Back) and SMSoS (SMS over SGs). It is used for Mobility management (MM) and paging procedures between the EPS (Evolved Packet Services) and CS (Circuit Switched) domain.

#### 21.1 VTY configuration

The SGs interface implementation in OsmoMSC is automatically active and requires only minimal configuration. When no specific configuration is provided OsmoMSC will listen on 0.0.0.0:29118 (SCTP) for incoming connections.

This is sufficient in the most configurations, but in larger installations, where services are either tied to specific interfaces and/or more instances of OsmoMSC run in parallel, a custom configuration is necessary.
The user has the option to configure the IP address (local-ip) and the SCTP port (local-port) and also the vlr-name that OsmoMSC uses to identify itself towards the MME. It should be noted that the vlr-name is usually the DNS name for the IP address of the VLR/MSC, so IP address used and the vlr-name should match the DNS server entry.

```
sgs
local-ip 127.0.0.1
local-port 29118
vlr-name vlr.example.net
```

In order to fine tune the behavior of the SGs interface the user also has control over the relevant timers (ts5, ts6-2, ts7, ts11, ts14, ts15) and counters (ns7, ns11). Each timer and counter has to be configured separately. In the following example we change the value of ts and ns11.

```
sgs
timer ts7 23
counter ns11 100
```

**Note**
In case multiple instances of OsmoMSC run in parallel, it is advised to use a different vlr-name for each instance. In any case it must be ensured that the SGs interface of each instance is bound to a different IP address and/or port.

### 21.2 Connection monitoring

The user can use the VTY command `show sgs-connections` to list the MMEs that are currently connected to OsmoMSC.

### 22 Osmocom Control Interface

The VTY interface as described in Section 11 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.

#### 22.1 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).

![IPA header for control protocol](image_url)
Inside the IPA header is a single byte of extension header with protocol ID 0x00 which indicates the control interface.

![Figure 14: IPA extension header for control protocol](image)

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

The fields specified below follow the following meaning:

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

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

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

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

### 22.1.1 GET operation

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

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

![Figure 17: Control Interface SET operation (successful outcome)](image)

![Figure 18: Control Interface SET operation (unsuccessful outcome)](image)

22.1.3 TRAP operation

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

![Figure 19: Control Interface TRAP operation](image)

22.2 Common variables

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

<table>
<thead>
<tr>
<th>Name</th>
<th>Access</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>counter.*</td>
<td>RO</td>
<td></td>
<td>Get counter value.</td>
</tr>
<tr>
<td>rate_ctr.*</td>
<td>RO</td>
<td></td>
<td>Get list of rate counter groups.</td>
</tr>
<tr>
<td>rate_ctr.IN.GN.GI.name</td>
<td>RO</td>
<td></td>
<td>Get value for interval IN of rate counter name which belong to group named GN with index GI.</td>
</tr>
</tbody>
</table>
Those read-only variables allow to get value of arbitrary counter using its name.
For example "rate_ctr.per_hour.bsc.0.handover:timeout" is the number of handover timeouts per hour.
Of course for that to work the program in question have to register corresponding counter names and groups using libosmocore functions.

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

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

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

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

### 22.3 Control Interface python examples

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

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

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

Internally it uses "rate_ctr.*" variable described in Section 22.2 to get the list of counter groups and than request all the counters in each group. Applications interested in individual metrics can request it directly using rate_ctr2csv.py as an example.

#### 22.3.1 Getting rate counters

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

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

#### 22.3.2 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
```
22.3.3 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
```

22.3.4 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
```

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

23 Generic Subscriber Update Protocol

23.1 General

This chapter describes the remote protocol that is used by OsmoSGSN and OsmoMSC to update and manage the local subscriber list in OsmoHLR. Functionally, it resembles the interface between the SGSN/VLR on the one hand side, and HLR/AUC on the other side.

For more information, see the specification of the Gr interface (3GPP TS 03.60).

Traditionally, the GSM MAP (Mobile Application Part) protocol is used for this purpose, running on top of a full telecom signalling protocol stack of MTP2/MTP3/SCCP/TCAP, or any of the SIGTRAN alternatives.

In order to avoid many of the complexities of MAP, which are difficult to implement in the plain C language environment of the Osmocom cellular network elements like the SGSN, we introduce the GSUP protocol.

The GSUP protocol and the messages are designed after the corresponding MAP messages (see 3GPP TS 09.02) with the following main differences:

- The encoding uses TLV structures instead of ASN.1 BER
- Segmentation is not used, i.e. we rely on the fact that the underlying transport protocol can transport signalling messages of any size.

23.2 Connection

The protocol expects that a reliable, ordered, packet boundaries preserving connection is used (e.g. IPA over TCP). The remote peer is either a service that understands the protocol natively or a wrapper service that maps the messages to/from real MAP messages that can be used to directly communicate with an HLR.

23.3 Using IPA

By default, the following identifiers should be used:

- IPA Stream ID: 0xEE (OSMO)
- IPA OSMO protocol extension: 0x05

For more information about the IPA multiplex, please see the OsmoBTS Abis/IP Specification.
23.4 Procedures

23.4.1 Authentication management

The SGSN or VLR sends a SEND_AUTHENTICATION_INFO_REQ message containing the MS’s IMSI to the peer. On errors, especially if authentication info is not available for that IMSI, the peer returns a SEND_AUTHENTICATION_INFO_ERR message. Otherwise the peer returns a SEND_AUTHENTICATION_INFO_RES message. If this message contains at least one authentication tuple, the SGSN or VLR replaces all tuples that are assigned to the subscriber. If the message doesn’t contain any tuple the SGSN or VLR may reject the Attach Request. (see 3GPP TS 09.02, 25.5.6)

![Diagrams showing Send Authentication Info (Normal Case) and Erroneous Case]

23.4.2 Reporting of Authentication Failure

Using this procedure, the SGSN or VLR reports authentication failures to the HLR.

![Diagrams showing Authentication Failure Report (Normal Case)]

23.4.3 Location Updating

The SGSN or VLR sends a UPDATE_LOCATION_REQ to the peer. If the request is denied by the network, the peer returns an UPDATE_LOCATION_ERR message to the SGSN or VLR. Otherwise the peer returns an UPDATE_LOCATION_RES message containing all information fields that shall be inserted into the subscriber record. If the PDP info complete information element is set in the message, the SGSN or VLR clears existing PDP information fields in the subscriber record first. (see 3GPP TS 09.02, 19.1.1.8)

![Diagrams showing Update Location (Normal Case)]
23.4.4 Location Cancellation

Using the Location Cancellation procedure, the Network Peer (HLR) can request the SGSN or VLR to remove a subscriber record.

23.4.5 Purge MS

Using the Purge MS procedure, the SGSN or VLR can request purging of MS related state from the HLR. It is used after the SGSN or VLR detects that no radio contact has been established for a prolonged duration (i.e. longer than the periodic LU timeout). See 3GPP TS 23.012 Section 3.6.1.4 for a description of this procedure.

23.4.6 Delete Subscriber Data

Using the Delete Subscriber Data procedure, the Peer (HLR) can remove some of the subscriber data from the SGSN or VLR. This is used in case the subscription details (e.g. PDP Contexts / APNs) change while the subscriber is registered to that SGSN VLR.
23.4.7 Check IMEI

The VLR asks the EIR to check if a new ME’s IMEI is acceptable or not. The EIR may implement a blacklist or whitelist and reject the IMEI based on that. Against the original purpose of the Check IMEI Procedure, this could also be used to save the IMEI in the HLR DB.

![Check IMEI (Normal Case)](image)

23.5 Procedures (E Interface)

The E interface connects two MSCs in the traditional GSM MAP world. It is used for the inter-MSC handover. In GSUP, we don’t need that extra connection, as we route the messages over the GSUP server (OsmoHLR) instead.

Whenever MSC-A is sending to MSC-B, and vice-versa, the message needs to pass through the GSUP server. In order to make the following message sequence charts easier to read, this step has been omitted.

23.5.1 E Handover

MSC-A has an active RAN connection and hands it over to MSC-B.

![E Handover (Normal Case)](image)

23.5.2 E Subsequent Handover

MSC-B has an active RAN connection, and asks MSC-A to hand it over to MSC-B’.
23.5.3 E Forward and Process Access Signalling

MSC-A is forwarding a message from its BSS (Base Station Subsystem) to MSC-B. MSC-B forwards the message to its BSS, and answers to MSC-A with a Process Access Signalling Request.

23.5.4 E Routing Error

The GSUP server can not route any of the requests above, and responds with an E Routing Error. Possible reasons for not being able to route the message are missing routing IEs, a mismatching source name IE (Section 23.7.31), the destination not being connected to the GSUP server or a failed attempt to send the message from the GSUP sever to the destination. To figure out, what went wrong in detail, refer to the GSUP server’s logs.

In the traditional GSM MAP world, the participants of an E procedure are directly connected, hence this routing error message does not exist in MAP.
23.6 Message Format

23.6.1 General

Every message is based on the following message format

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Message Type</td>
<td>Section 23.7.1</td>
<td>M</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
</tbody>
</table>

If a numeric range is indicated in the presence column, multiple information elements with the same tag may be used in sequence. The information elements shall be sent in the given order. Nevertheless after the generic part the receiver shall be able to received them in any order. Unknown IE shall be ignored.

Besides a numeric range, the presence column may have M (Mandatory), O (Optional) or C (Conditional). The format column holds either V (Value) or TLV (Tag Length Value).

23.6.2 Send Authentication Info Request

Direction: SGSN / VLR ⇒ HLR

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Message Type</td>
<td>Section 23.7.1</td>
<td>M</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>28</td>
<td>CN Domain</td>
<td>Section 23.7.15</td>
<td>O</td>
<td>TLV</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>AUTS</td>
<td>Section 23.7.13</td>
<td>C</td>
<td>TLV</td>
<td>18</td>
</tr>
<tr>
<td>20</td>
<td>RAND</td>
<td>Section 23.7.7</td>
<td>C</td>
<td>TLV</td>
<td>18</td>
</tr>
<tr>
<td>05</td>
<td>PDP info</td>
<td>Section 23.7.3</td>
<td>C</td>
<td>TLV</td>
<td>2-N</td>
</tr>
</tbody>
</table>

The conditional AUTS and RAND IEs are both present in case the SIM (via UE) requests an UMTS AKA re-synchronization procedure. Either both optional IEs are present, or none of them.

The conditional PDP Info IE is only present in the CEA1 interface used by the ePDG. It should contain the PDP Context ID, PDP Address (dynamic addressing) and Access Point Name IEs.

23.6.3 Send Authentication Info Error

Direction: HLR ⇒ SGSN / VLR

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Message Type</td>
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<td>M</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>02</td>
<td>Cause</td>
<td>Section 23.7.26</td>
<td>M</td>
<td>TLV</td>
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</tr>
</tbody>
</table>

23.6.4 Send Authentication Info Response

Direction: HLR ⇒ SGSN / VLR

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<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Message Type</td>
<td>Section 23.7.1</td>
<td>M</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>03</td>
<td>Auth Tuple</td>
<td>Section 23.7.6</td>
<td>0-5</td>
<td>TLV</td>
<td>36</td>
</tr>
</tbody>
</table>
23.6.5 Authentication Failure Report

Direction: SGSN / VLR ⇒ HLR

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</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>28</td>
<td>CN Domain</td>
<td>Section 23.7.15</td>
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<td>TLV</td>
<td>3</td>
</tr>
</tbody>
</table>

23.6.6 Update Location Request

Direction: SGSN / VLR ⇒ HLR

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<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
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<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>28</td>
<td>CN Domain</td>
<td>Section 23.7.15</td>
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<td>TLV</td>
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</tr>
</tbody>
</table>

23.6.7 Update Location Error

Direction: HLR ⇒ SGSN / VLR

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<th>Format</th>
<th>Length</th>
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<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>02</td>
<td>Cause</td>
<td>Section 23.7.26</td>
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<td>TLV</td>
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</tbody>
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23.6.8 Update Location Result

Direction: HLR ⇒ SGSN / VLR

<table>
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<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>08</td>
<td>MSISDN</td>
<td>Section 23.7.20</td>
<td>O</td>
<td>TLV</td>
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</tr>
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</tr>
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<td>05</td>
<td>PDP info</td>
<td>Section 23.7.3</td>
<td>O</td>
<td>TLV</td>
<td>2-N</td>
</tr>
</tbody>
</table>

If the PDP info complete IE is present, the old PDP info list shall be cleared.

23.6.9 Location Cancellation Request

Direction: HLR ⇒ SGSN / VLR

<table>
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<tr>
<th>IEI</th>
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<tbody>
<tr>
<td>01</td>
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<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>28</td>
<td>CN Domain</td>
<td>Section 23.7.15</td>
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<tr>
<td>06</td>
<td>Cancellation type</td>
<td>Section 23.7.16</td>
<td>O</td>
<td>TLV</td>
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</table>
23.6.10 Location Cancellation Error

Direction: SGSN / VLR ⇒ HLR

TODO

23.6.11 Location Cancellation Result

Direction: SGSN / VLR ⇒ HLR

<table>
<thead>
<tr>
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<th>Format</th>
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<tbody>
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<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>28</td>
<td>CN Domain</td>
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</tr>
</tbody>
</table>

23.6.12 Purge MS Request

Direction: SGSN / VLR ⇒ HLR

<table>
<thead>
<tr>
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<th>IE</th>
<th>Type</th>
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<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>28</td>
<td>CN Domain</td>
<td>Section 23.7.15</td>
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<td>TLV</td>
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</tr>
</tbody>
</table>

23.6.13 Purge MS Error

Direction: HLR ⇒ SGSN / VLR

<table>
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<tr>
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<th>Type</th>
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<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>02</td>
<td>Cause</td>
<td>Section 23.7.26</td>
<td>M</td>
<td>TLV</td>
<td>3</td>
</tr>
</tbody>
</table>

23.6.14 Purge MS Result

Direction: HLR ⇒ SGSN / VLR

<table>
<thead>
<tr>
<th>IEI</th>
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<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>07</td>
<td>Freeze P-TMSI</td>
<td>Section 23.7.18</td>
<td>M</td>
<td>TLV</td>
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</tr>
</tbody>
</table>

23.6.15 Insert Subscriber Data Request

Direction: HLR ⇒ SGSN / VLR

<table>
<thead>
<tr>
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<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>28</td>
<td>CN Domain</td>
<td>Section 23.7.15</td>
<td>O</td>
<td>TLV</td>
<td>3</td>
</tr>
<tr>
<td>08</td>
<td>MSISDN</td>
<td>Section 23.7.20</td>
<td>O</td>
<td>TLV</td>
<td>0-9</td>
</tr>
<tr>
<td>09</td>
<td>HLR Number</td>
<td>Section 23.7.25</td>
<td>O</td>
<td>TLV</td>
<td>0-9</td>
</tr>
</tbody>
</table>
If the PDP info complete IE is present, the old PDP info list shall be cleared.

### 23.6.16 Insert Subscriber Data Error

**Direction:** SGSN / VLR ⇒ HLR

<table>
<thead>
<tr>
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<th>Length</th>
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<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
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<td>2-10</td>
</tr>
</tbody>
</table>

### 23.6.17 Insert Subscriber Data Result

**Direction:** SGSN / VLR ⇒ HLR

<table>
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<tr>
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<th>IE</th>
<th>Type</th>
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<th>Format</th>
<th>Length</th>
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</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
</tbody>
</table>

### 23.6.18 Delete Subscriber Data Request

**Direction:** HLR ⇒ SGSN / VLR

<table>
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<tr>
<th>IEI</th>
<th>IE</th>
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<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
</tbody>
</table>

### 23.6.19 Delete Subscriber Data Error

**Direction:** SGSN / VLR ⇒ HLR

<table>
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<th>Type</th>
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<th>Length</th>
</tr>
</thead>
<tbody>
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<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
</tbody>
</table>

### 23.6.20 Delete Subscriber Data Result

**Direction:** HLR ⇒ SGSN / VLR

<table>
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<tr>
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<th>Format</th>
<th>Length</th>
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</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
</tbody>
</table>
23.6.21 Process Supplementary Service Request

Direction: bidirectional

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.1</td>
<td>M</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>Session ID</td>
<td>Section 23.8.1</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
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<td>Section 23.8.2</td>
<td>M</td>
<td>TLV</td>
<td>6</td>
</tr>
<tr>
<td>35</td>
<td>Supplementary</td>
<td>Section 23.7.27</td>
<td>O</td>
<td>TLV</td>
<td>2-…</td>
</tr>
</tbody>
</table>

This message is used in both directions in case of USSD, because it is not known is it request or response without parsing the GSM 04.80 payload.

23.6.22 Process Supplementary Service Error

Direction: EUSE / HLR ⇒ MSC

<table>
<thead>
<tr>
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<th>IE</th>
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<th>Format</th>
<th>Length</th>
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<tbody>
<tr>
<td>01</td>
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<td>M</td>
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<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>31</td>
<td>Session State</td>
<td>Section 23.8.2</td>
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<td>TLV</td>
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</tr>
<tr>
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</tr>
</tbody>
</table>

23.6.23 Process Supplementary Service Response

Direction: EUSE / HLR ⇒ MSC

<table>
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<th>Length</th>
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<td>M</td>
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<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
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<td>Session State</td>
<td>Section 23.8.2</td>
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<td>TLV</td>
<td>6</td>
</tr>
<tr>
<td>35</td>
<td>Supplementary</td>
<td>Section 23.7.27</td>
<td>O</td>
<td>TLV</td>
<td>2-…</td>
</tr>
</tbody>
</table>

The purpose of this message is not clear yet. Probably, it can be used to notify the MSC that a structured supplementary service is successfully activated or deactivated, etc.

23.6.24 MO-forwardSM Request

Direction: MSC / SGSN ⇒ SMSC (via HLR)

<table>
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<tr>
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<th>Length</th>
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<tbody>
<tr>
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<td>Section 23.7.1</td>
<td>M</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>40</td>
<td>SM-RP-MR (Message Reference)</td>
<td>Section 23.8.3</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>41</td>
<td>SM-RP-DA (Destination Address)</td>
<td>Section 23.8.4</td>
<td>M</td>
<td>TLV</td>
<td>2-…</td>
</tr>
<tr>
<td>42</td>
<td>SM-RP-OA (Originating Address)</td>
<td>Section 23.8.5</td>
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<td>2-…</td>
</tr>
<tr>
<td>43</td>
<td>SM-RP-UI (SM TPDU)</td>
<td>Section 23.8.7</td>
<td>M</td>
<td>TLV</td>
<td>1-…</td>
</tr>
</tbody>
</table>

This message is used to forward MO short messages from MSC / SGSN to an SMSC. The corresponding MAP service is MAP-MO-FORWARD-SHORT-MESSAGE, see 3GPP TS 29.002, section 12.2.
23.6.25 MO-forwardSM Error

Direction: SMSC (via HLR) ⇒ MSC / SGSN

<table>
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<th>Presence</th>
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<td>V</td>
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<td>44</td>
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<td>Section 23.8.8</td>
<td>M</td>
<td>TLV</td>
</tr>
<tr>
<td>43</td>
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<td>SM-RP-UI (diagnostic field)</td>
<td>Section 23.8.7</td>
<td>O</td>
<td>TLV</td>
</tr>
</tbody>
</table>

This message is used to indicate a negative result of an earlier MO short message delivery. The corresponding MAP service is MAP-MO-FORWARD-SHORT-MESSAGE, see 3GPP TS 29.002, section 12.2.

23.6.26 MO-forwardSM Result

Direction: SMSC (via HLR) ⇒ MSC / SGSN

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<td>Section 23.8.3</td>
<td>M</td>
<td>TLV</td>
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This message is used to indicate a successful result of an earlier MO short message delivery. The corresponding MAP service is MAP-MO-FORWARD-SHORT-MESSAGE, see 3GPP TS 29.002, section 12.2.

23.6.27 MT-forwardSM Request

Direction: SMSC (via HLR) ⇒ MSC / SGSN

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<td>V</td>
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<td>Section 23.8.4</td>
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</tr>
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<td>TLV</td>
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<tr>
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<td>M</td>
<td>TLV</td>
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<td>Section 23.8.9</td>
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<td>TLV</td>
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</table>

This message is used to forward MT short messages from an SMSC to MSC / SGSN. The corresponding MAP service is MAP-MT-FORWARD-SHORT-MESSAGE, see 3GPP TS 29.002, section 12.9.

23.6.28 MT-forwardSM Error

Direction: MSC / SGSN ⇒ SMSC (via HLR)

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<td>V</td>
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<td>SM-RP-MR (Message Reference)</td>
<td>Section 23.8.3</td>
<td>M</td>
<td>TLV</td>
</tr>
<tr>
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<td>M</td>
<td>TLV</td>
</tr>
<tr>
<td>43</td>
<td></td>
<td>SM-RP-UI (diagnostic field)</td>
<td>Section 23.8.7</td>
<td>O</td>
<td>TLV</td>
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</table>

This message is used to indicate a negative result of an earlier MT short message delivery. The corresponding MAP service is MAP-MT-FORWARD-SHORT-MESSAGE, see 3GPP TS 29.002, section 12.9.
23.6.29  MT-forwardSM Result

Direction: MSC / SGSN ⇒ SMSC (via HLR)

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<td>V</td>
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<td>Section 23.8.3</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
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</table>

This message is used to indicate a successful result of an earlier MT short message delivery. The corresponding MAP service is MAP-MT-FORWARD-SHORT-MESSAGE, see 3GPP TS 29.002, section 12.9.

23.6.30  READY-FOR-SM Request

Direction: MSC / SGSN ⇒ SMSC (via HLR)

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<td>V</td>
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<td>46</td>
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<td>Section 23.8.10</td>
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This message is used between the MSC / SGSN and an SMSC when a subscriber indicates memory available situation (see TS GSM 04.11, section 7.3.2). The corresponding MAP service is MAP-READY-FOR-SM, see 3GPP TS 29.002, section 12.4.

23.6.31  READY-FOR-SM Error

Direction: SMSC (via HLR) ⇒ MSC / SGSN

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<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>43</td>
<td>SM-RP-UI (diagnostic field)</td>
<td>Section 23.8.7</td>
<td>O</td>
<td>TLV</td>
<td>1-...</td>
</tr>
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</table>

This message is used to indicate a negative result of an earlier MO SMMA (Memory Available) indication. The corresponding MAP service is MAP-READY-FOR-SM, see 3GPP TS 29.002, section 12.4.

23.6.32  READY-FOR-SM Result

Direction: SMSC (via HLR) ⇒ MSC / SGSN

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This message is used to indicate a successful result of an earlier MO SMMA (Memory Available) indication. The corresponding MAP service is MAP-READY-FOR-SM, see 3GPP TS 29.002, section 12.4.

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23.6.33 CHECK-IMEI Request

Direction: VLR ⇒ EIR (via HLR)

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23.6.34 CHECK-IMEI Error

Direction: EIR (via HLR) ⇒ VLR

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23.6.35 CHECK-IMEI Result

Direction: EIR (via HLR) ⇒ VLR

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</table>

23.6.36 E Prepare Handover Request

Direction: MSC-A=MSC-I ⇒ MSC-B=MSC-T (via HLR)

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</table>

23.6.37 E Prepare Handover Error

Direction: MSC-B=MSC-T ⇒ MSC-A=MSC-I (via HLR)

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23.6.38  E Prepare Handover Result
Direction: MSC-B=MSC-T ⇒ MSC-A=MSC-I (via HLR)

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<td>TLV</td>
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23.6.39  E Prepare Subsequent Handover Request
Direction: MSC-B=MSC-I ⇒ MSC-A (via HLR)

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23.6.40  E Prepare Subsequent Handover Error
Direction: MSC-A ⇒ MSC-B=MSC-I (via HLR)

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23.6.41  E Prepare Subsequent Handover Result
Direction: MSC-A ⇒ MSC-B=MSC-I (via HLR)

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23.6.42  E Send End Signal Request
Direction: MSC-B=MSC-T ⇒ MSC-A=MSC-I (via HLR)
### 23.6.43 E Send End Signal Error

Direction: MSC-A=MSC-I ⇒ MSC-B=MSC-T (via HLR)

<table>
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### 23.6.44 E Send End Signal Result

Direction: MSC-A ⇒ MSC-B=MSC-I (via HLR)

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<td>2-10</td>
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### 23.6.45 E Process Access Signalling Request

Direction: MSC-B=MSC-T ⇒ MSC-A=MSC-I (via HLR)

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<tr>
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<td>Message Class</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>60</td>
<td>Source Name</td>
<td>Section 23.7.30</td>
<td>M</td>
<td>TLV</td>
<td>3</td>
</tr>
<tr>
<td>61</td>
<td>Destination Name</td>
<td>Section 23.7.31</td>
<td>M</td>
<td>TLV</td>
<td>2-...</td>
</tr>
<tr>
<td>62</td>
<td>AN-APDU</td>
<td>Section 23.7.32</td>
<td>M</td>
<td>TLV</td>
<td>2-...</td>
</tr>
</tbody>
</table>

### 23.6.46 E Forward Access Signalling Request

Direction: MSC-A ⇒ MSC-B=MSC-I (via HLR)

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Message Type</td>
<td>M</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>0a</td>
<td>Message Class</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>60</td>
<td>Source Name</td>
<td>Section 23.7.30</td>
<td>M</td>
<td>TLV</td>
<td>3</td>
</tr>
<tr>
<td>61</td>
<td>Destination Name</td>
<td>Section 23.7.31</td>
<td>M</td>
<td>TLV</td>
<td>2-...</td>
</tr>
</tbody>
</table>
### 23.6.47 E Close

Direction: MSC-A ⇒ MSC-B (via HLR)

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>Destination Name</td>
<td>Section 23.7.32</td>
<td>M</td>
<td>TLV</td>
<td>2-...</td>
</tr>
<tr>
<td>62</td>
<td>AN-APDU</td>
<td>Section 23.7.33</td>
<td>M</td>
<td>TLV</td>
<td>2-...</td>
</tr>
</tbody>
</table>

### 23.6.48 E Abort

This message was added to GSUP for the inter-MSC handover. But so far it is not used yet.

### 23.6.49 E Routing Error

Direction: GSUP Server (HLR) ⇒ GSUP Client (MSC)

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>0a</td>
<td>Message Class</td>
<td>Section 23.7.30</td>
<td>M</td>
<td>TLV</td>
<td>3</td>
</tr>
<tr>
<td>60</td>
<td>Source Name</td>
<td>Section 23.7.31</td>
<td>M</td>
<td>TLV</td>
<td>2-...</td>
</tr>
<tr>
<td>61</td>
<td>Destination Name</td>
<td>Section 23.7.32</td>
<td>M</td>
<td>TLV</td>
<td>2-...</td>
</tr>
<tr>
<td>30</td>
<td>Session ID</td>
<td>Section 23.8.1</td>
<td>O</td>
<td>TLV</td>
<td>6</td>
</tr>
<tr>
<td>31</td>
<td>Session State</td>
<td>Section 23.8.2</td>
<td>O</td>
<td>TLV</td>
<td>3</td>
</tr>
</tbody>
</table>

### 23.6.50 ePDG Tunnel Request

Direction: GSUP Client (strongswan) ⇒ GSUP Server (ePDG)

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>0a</td>
<td>Message Class</td>
<td>Section 23.7.30</td>
<td>M</td>
<td>TLV</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>PCO</td>
<td>Section 23.7.24</td>
<td>O</td>
<td>TLV</td>
<td>1-...</td>
</tr>
<tr>
<td>28</td>
<td>CN Domain</td>
<td>Section 23.7.15</td>
<td>O</td>
<td>TLV</td>
<td>3</td>
</tr>
<tr>
<td>60</td>
<td>Source Name</td>
<td>Section 23.7.31</td>
<td>O</td>
<td>TLV</td>
<td>2-...</td>
</tr>
</tbody>
</table>

### 23.6.51 ePDG Tunnel Error

Direction: GSUP Server (ePDG) ⇒ GSUP Client (strongswan)

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>IMSI</td>
<td>Section 23.7.19</td>
<td>M</td>
<td>TLV</td>
<td>2-10</td>
</tr>
<tr>
<td>0a</td>
<td>Message Class</td>
<td>Section 23.7.30</td>
<td>M</td>
<td>TLV</td>
<td>3</td>
</tr>
</tbody>
</table>
### 23.6.52 ePDG Tunnel Result

**Direction:** GSUP Server (ePDG) ⇒ GSUP Client (strongswan)

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>Cause</td>
<td>Section 23.7.26</td>
<td>M</td>
<td>TLV</td>
<td>3</td>
</tr>
</tbody>
</table>

#### 23.7 Information Elements

##### 23.7.1 Message Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x04</td>
<td>Update Location Request</td>
<td>Section 23.6.6</td>
</tr>
<tr>
<td>0x05</td>
<td>Update Location Error</td>
<td>Section 23.6.7</td>
</tr>
<tr>
<td>0x06</td>
<td>Update Location Result</td>
<td>Section 23.6.8</td>
</tr>
<tr>
<td>0x08</td>
<td>Send Authentication Info Request</td>
<td>Section 23.6.9</td>
</tr>
<tr>
<td>0x09</td>
<td>Send Authentication Info Error</td>
<td>Section 23.6.10</td>
</tr>
<tr>
<td>0x0a</td>
<td>Send Authentication Info Result</td>
<td>Section 23.6.11</td>
</tr>
<tr>
<td>0x0c</td>
<td>Authentication Failure Report</td>
<td>Section 23.6.12</td>
</tr>
<tr>
<td>0x0d</td>
<td>Purge MS Request</td>
<td>Section 23.6.13</td>
</tr>
<tr>
<td>0x0e</td>
<td>Purge MS Error</td>
<td>Section 23.6.14</td>
</tr>
<tr>
<td>0x10</td>
<td>Purge MS Result</td>
<td>Section 23.6.15</td>
</tr>
<tr>
<td>0x11</td>
<td>Insert Subscriber Data Request</td>
<td>Section 23.6.16</td>
</tr>
<tr>
<td>0x12</td>
<td>Insert Subscriber Data Error</td>
<td>Section 23.6.17</td>
</tr>
<tr>
<td>Type</td>
<td>Name</td>
<td>Section</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Insert Subscriber Data Result</td>
<td>Section 23.6.17</td>
<td></td>
</tr>
<tr>
<td>Delete Subscriber Data Request</td>
<td>Section 23.6.18</td>
<td>0x15</td>
</tr>
<tr>
<td>Delete Subscriber Data Error</td>
<td>Section 23.6.19</td>
<td></td>
</tr>
<tr>
<td>Delete Subscriber Data Result</td>
<td>Section 23.6.20</td>
<td>0x1c</td>
</tr>
<tr>
<td>Location Cancellation Request</td>
<td>Section 23.6.9</td>
<td></td>
</tr>
<tr>
<td>Location Cancellation Error</td>
<td>Section 23.6.10</td>
<td>0x1d</td>
</tr>
<tr>
<td>Supplementary Service Request</td>
<td>Section 23.6.21</td>
<td>0x20</td>
</tr>
<tr>
<td>Supplementary Service Error</td>
<td>Section 23.6.22</td>
<td></td>
</tr>
<tr>
<td>Supplementary Service Result</td>
<td>Section 23.6.23</td>
<td>0x22</td>
</tr>
<tr>
<td>MO-forwardSM Request</td>
<td>Section 23.6.24</td>
<td></td>
</tr>
<tr>
<td>MO-forwardSM Error</td>
<td>Section 23.6.25</td>
<td>0x25</td>
</tr>
<tr>
<td>MO-forwardSM Result</td>
<td>Section 23.6.26</td>
<td></td>
</tr>
<tr>
<td>MT-forwardSM Request</td>
<td>Section 23.6.27</td>
<td>0x28</td>
</tr>
<tr>
<td>MT-forwardSM Error</td>
<td>Section 23.6.28</td>
<td></td>
</tr>
<tr>
<td>MT-forwardSM Result</td>
<td>Section 23.6.29</td>
<td>0x2a</td>
</tr>
<tr>
<td>READY-FOR-SM Request</td>
<td>Section 23.6.30</td>
<td></td>
</tr>
<tr>
<td>READY-FOR-SM Error</td>
<td>Section 23.6.31</td>
<td>0x2d</td>
</tr>
<tr>
<td>READY-FOR-SM Result</td>
<td>Section 23.6.32</td>
<td></td>
</tr>
<tr>
<td>CHECK-IMEI Request</td>
<td>Section 23.6.33</td>
<td>0x30</td>
</tr>
<tr>
<td>CHECK-IMEI Error</td>
<td>Section 23.6.34</td>
<td></td>
</tr>
<tr>
<td>CHECK-IMEI Result</td>
<td>Section 23.6.35</td>
<td>0x32</td>
</tr>
<tr>
<td>Type</td>
<td>Name</td>
<td>Section</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>E Prepare Handover Request</td>
<td>0x35</td>
<td>Section 23.6.36</td>
</tr>
<tr>
<td>E Prepare Handover Error</td>
<td>0x36</td>
<td>Section 23.6.37</td>
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<tr>
<td>E Prepare Handover Result</td>
<td>0x38</td>
<td>Section 23.6.38</td>
</tr>
<tr>
<td>E Prepare Subsequent Handover Request</td>
<td>0x39</td>
<td>Section 23.6.38</td>
</tr>
<tr>
<td>E Prepare Subsequent Handover Error</td>
<td>0x3a</td>
<td>Section 23.6.40</td>
</tr>
<tr>
<td>E Prepare Subsequent Handover Result</td>
<td>0x3c</td>
<td>Section 23.6.40</td>
</tr>
<tr>
<td>E Send End Signal Request</td>
<td>0x3d</td>
<td>Section 23.6.42</td>
</tr>
<tr>
<td>E Send End Signal Error</td>
<td>0x3e</td>
<td>Section 23.6.42</td>
</tr>
<tr>
<td>E Send End Signal Result</td>
<td>0x40</td>
<td>Section 23.6.44</td>
</tr>
<tr>
<td>E Process Access Signalling Request</td>
<td>0x44</td>
<td>Section 23.6.46</td>
</tr>
<tr>
<td>E Forward Access Signalling Request</td>
<td>0x47</td>
<td>Section 23.6.46</td>
</tr>
<tr>
<td>E Close</td>
<td>0x4B</td>
<td>Section 23.6.48</td>
</tr>
<tr>
<td>E Abort</td>
<td>0x4E</td>
<td>Section 23.6.48</td>
</tr>
<tr>
<td>ePDG Tunnel Request</td>
<td>0x51</td>
<td>Section 23.6.50</td>
</tr>
<tr>
<td>ePDG Tunnel Error</td>
<td>0x52</td>
<td>Section 23.6.50</td>
</tr>
<tr>
<td>ePDG Tunnel Result</td>
<td>0x54</td>
<td>Section 23.6.52</td>
</tr>
</tbody>
</table>

The category of the message is indicated by the last two bits of the type. Request, Error and Result messages only differ in these last two bits, so it is trivial to transform them.

<table>
<thead>
<tr>
<th>Ending Bits</th>
<th>Message Category</th>
</tr>
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<tbody>
<tr>
<td>00</td>
<td>Request</td>
</tr>
<tr>
<td>01</td>
<td>Error</td>
</tr>
<tr>
<td>10</td>
<td>Result</td>
</tr>
<tr>
<td>11</td>
<td>Other</td>
</tr>
</tbody>
</table>
23.7.2 IP Address

The value part is encoded like in the Packet data protocol address IE defined in 3GPP TS 24.008, Chapter 10.5.6.4. PDP type organization must be set to *IETF allocated address*.

23.7.3 PDP Info

This is a container for information elements describing a single PDP.

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>PDP Info IEI</td>
<td>Section 23.7.17</td>
<td>M</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Length of PDP Info IE</td>
<td></td>
<td>M</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>PDP Context ID</td>
<td>Section 23.7.5</td>
<td>C</td>
<td>TLV</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>PDP Address</td>
<td>Section 23.7.4</td>
<td>C</td>
<td>TLV</td>
<td>4-24</td>
</tr>
<tr>
<td>12</td>
<td>Access Point Name</td>
<td>Section 23.7.21</td>
<td>C</td>
<td>TLV</td>
<td>3-102</td>
</tr>
<tr>
<td>13</td>
<td>Quality of Service</td>
<td>Section 23.7.22</td>
<td>O</td>
<td>TLV</td>
<td>1-20</td>
</tr>
<tr>
<td>14</td>
<td>PDP-Charging Characteristics</td>
<td>Section 23.7.23</td>
<td>O</td>
<td>TLV</td>
<td>4</td>
</tr>
</tbody>
</table>

The conditional IE are mandatory unless mentioned otherwise.

23.7.4 PDP Address

The value part is encoded like in the Packet data protocol address IE defined in 3GPP TS 24.008, Chapter 10.5.6.4. Hence this value also relates to End User Address (EUA) IE defined in 3GPP TS 29.060, 7.7.27. The PDP type organization value must be set to *IETF allocated address*.
The spare bits are left undefined. While 3GPP TS 29.060 7.7.27 defines them as \texttt{1 1 1 1}, there are MAP traces where these bits are set to \texttt{0 0 0 0}. So the receiver shall ignore these bits.

Examples:

- IPv4: PDP type org: 1 (IETF), PDP type number: 0x21, 0 bytes address (dynamic addressing)
- IPv4: PDP type org: 1 (IETF), PDP type number: 0x21, 4 bytes address
- IPv6: PDP type org: 1 (IETF), PDP type number: 0x57, 16 bytes address
- IPv6: PDP type org: 1 (IETF), PDP type number: 0x8D, 20 bytes address (v4+v6)
23.7.5 PDP Context ID

The PDP type context ID IE consists of a single integer byte wrapped in a TLV.

![PDP context ID IE diagram]

23.7.6 Auth tuple

This is a container for information elements describing a single authentication tuple.

<table>
<thead>
<tr>
<th>IEI</th>
<th>IE</th>
<th>Type</th>
<th>Presence</th>
<th>Format</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auth Tuple IEI</td>
<td>Section 23.7.17</td>
<td>M V 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of Auth Tuple IE</td>
<td></td>
<td>M V 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>RAND</td>
<td>Section 23.7.7</td>
<td>M</td>
<td>TLV</td>
<td>18</td>
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<td>21</td>
<td>SRES</td>
<td>Section 23.7.8</td>
<td>M</td>
<td>TLV</td>
<td>6</td>
</tr>
<tr>
<td>22</td>
<td>Kc</td>
<td>Section 23.7.9</td>
<td>M</td>
<td>TLV</td>
<td>10</td>
</tr>
<tr>
<td>23</td>
<td>IK</td>
<td>Section 23.7.10</td>
<td>C</td>
<td>TLV</td>
<td>18</td>
</tr>
<tr>
<td>24</td>
<td>CK</td>
<td>Section 23.7.11</td>
<td>C</td>
<td>TLV</td>
<td>18</td>
</tr>
<tr>
<td>25</td>
<td>AUTN</td>
<td>Section 23.7.12</td>
<td>C</td>
<td>TLV</td>
<td>18</td>
</tr>
<tr>
<td>27</td>
<td>RES</td>
<td>Section 23.7.14</td>
<td>C</td>
<td>TLV</td>
<td>2-18</td>
</tr>
</tbody>
</table>

The conditional IEs IK, CK, AUTN and RES are only present in case the subscriber supports UMTS AKA.

23.7.7 RAND

The 16-byte Random Challenge of the GSM Authentication Algorithm.

23.7.8 SRES

The 4-byte Authentication Result of the GSM Authentication Algorithm.

23.7.9 Kc

The 8-byte Encryption Key of the GSM Authentication and Key Agreement Algorithm.

23.7.10 IK

The 16-byte Integrity Protection Key generated by the UMTS Authentication and Key Agreement Algorithm.
23.7.11 CK

The 16-byte Ciphering Key generated by the UMTS Authentication and Key Agreement Algorithm.

23.7.12 AUTN

The 16-byte Authentication Nonce sent from network to USIM in the UMTS Authentication and Key Agreement Algorithm.

23.7.13 AUTS

The 14-byte Authentication Synchronization Nonce generated by the USIM in case the UMTS Authentication and Key Agreement Algorithm needs to re-synchronize the sequence counters between AUC and USIM.

23.7.14 RES

The (variable length, but typically 16 byte) Authentication Result generated by the USIM in the UMTS Authentication and Key Agreement Algorithm.

23.7.15 CN Domain

This single-byte information element indicates the Core Network Domain, i.e. if the message is related to Circuit Switched or Packet Switched services.

For backwards compatibility reasons, if no CN Domain IE is present within a request, the PS Domain is assumed.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>0x01</td>
<td>PS Domain</td>
</tr>
<tr>
<td>0x02</td>
<td>CS Domain</td>
</tr>
</tbody>
</table>

23.7.16 Cancellation Type
Table 12: Cancellation Type Number

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>Update Procedure</td>
</tr>
<tr>
<td>0x01</td>
<td>Subscription Withdrawn</td>
</tr>
</tbody>
</table>

### 23.7.17 IE Identifier (informational)

These are the standard values for the IEI. See the message definitions for the IEI that shall be used for the encoding.

Table 13: GSUP IE Identifiers

<table>
<thead>
<tr>
<th>IEI</th>
<th>Info Element</th>
<th>Type / Encoding</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td>IMSI</td>
<td>Mobile Identity, 3GPP TS 24.008 Ch. 10.5.1.4</td>
</tr>
<tr>
<td>0x02</td>
<td>Cause</td>
<td>Section 23.7.26</td>
</tr>
<tr>
<td>0x03</td>
<td>Auth Tuple</td>
<td>Section 23.7.6</td>
</tr>
<tr>
<td>0x04</td>
<td>PDP Info Compl</td>
<td>Section 23.7.18</td>
</tr>
<tr>
<td>0x05</td>
<td>PDP Info</td>
<td>Section 23.7.3</td>
</tr>
<tr>
<td>0x06</td>
<td>Cancel Type</td>
<td>Section 23.7.16</td>
</tr>
<tr>
<td>0x07</td>
<td>Freeze P-TMSI</td>
<td>Section 23.7.18</td>
</tr>
<tr>
<td>0x08</td>
<td>MSISDN</td>
<td>ISDN-AddressString/octet, Section 23.7.20</td>
</tr>
<tr>
<td>0x09</td>
<td>HLR Number</td>
<td>Section 23.7.25</td>
</tr>
<tr>
<td>0x0a</td>
<td>Message Class</td>
<td>Section 23.7.30</td>
</tr>
<tr>
<td>0x10</td>
<td>PDP Context ID</td>
<td>Section 23.7.5</td>
</tr>
<tr>
<td>0x11</td>
<td>PDP Address</td>
<td>[?].</td>
</tr>
<tr>
<td>0x12</td>
<td>Access Point Name</td>
<td>Section 23.7.21</td>
</tr>
<tr>
<td>0x13</td>
<td>QoS</td>
<td>Section 23.7.22</td>
</tr>
<tr>
<td>0x14</td>
<td>PDP-Charging Characteristics</td>
<td>Section 23.7.23</td>
</tr>
<tr>
<td>0x15</td>
<td>PCO</td>
<td>Section 23.7.24</td>
</tr>
<tr>
<td>0x20</td>
<td>RAND</td>
<td>Section 23.7.7</td>
</tr>
<tr>
<td>0x21</td>
<td>SRES</td>
<td>Section 23.7.8</td>
</tr>
<tr>
<td>0x22</td>
<td>Kc</td>
<td>Section 23.7.9</td>
</tr>
<tr>
<td>0x23</td>
<td>IK</td>
<td>Section 23.7.10</td>
</tr>
<tr>
<td>0x24</td>
<td>CK</td>
<td>Section 23.7.11</td>
</tr>
<tr>
<td>0x25</td>
<td>AUTN</td>
<td>Section 23.7.12</td>
</tr>
<tr>
<td>0x26</td>
<td>AUTS</td>
<td>Section 23.7.13</td>
</tr>
<tr>
<td>0x27</td>
<td>RES</td>
<td>Section 23.7.14</td>
</tr>
<tr>
<td>0x28</td>
<td>CN Domain</td>
<td>Section 23.7.15</td>
</tr>
<tr>
<td>0x30</td>
<td>Session ID</td>
<td>Section 23.8.1</td>
</tr>
<tr>
<td>0x31</td>
<td>Session State</td>
<td>Section 23.8.2</td>
</tr>
<tr>
<td>0x35</td>
<td>Supplementary Service Info</td>
<td>Section 23.7.27</td>
</tr>
<tr>
<td>0x40</td>
<td>SM-RP-MR (Message Reference)</td>
<td>Section 23.8.3</td>
</tr>
<tr>
<td>0x41</td>
<td>SM-RP-DA (Destination Address)</td>
<td>Section 23.8.4</td>
</tr>
<tr>
<td>0x42</td>
<td>SM-RP-OA (Originating Address)</td>
<td>Section 23.8.5</td>
</tr>
<tr>
<td>0x43</td>
<td>SM-RP-UI (SM TPDU)</td>
<td>Section 23.8.7</td>
</tr>
<tr>
<td>0x44</td>
<td>SM-RP-Cause (RP Cause value)</td>
<td>Section 23.8.8</td>
</tr>
<tr>
<td>0x45</td>
<td>SM-RP-MMS (More Messages to Send)</td>
<td>Section 23.8.9</td>
</tr>
<tr>
<td>0x46</td>
<td>SM Alert Reason</td>
<td>Section 23.8.10</td>
</tr>
<tr>
<td>0x50</td>
<td>IMEI</td>
<td>Section 23.7.28</td>
</tr>
<tr>
<td>0x51</td>
<td>IMEI Check Result</td>
<td>Section 23.7.29</td>
</tr>
<tr>
<td>0x60</td>
<td>Source Name</td>
<td>Section 23.7.31</td>
</tr>
<tr>
<td>0x61</td>
<td>Destination Name</td>
<td>Section 23.7.32</td>
</tr>
<tr>
<td>0x62</td>
<td>AN-APDU</td>
<td>Section 23.7.33</td>
</tr>
</tbody>
</table>
Table 13: (continued)

<table>
<thead>
<tr>
<th>IEI</th>
<th>Info Element</th>
<th>Type / Encoding</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x63</td>
<td>RR Cause</td>
<td>Section 23.7.34</td>
</tr>
<tr>
<td>0x64</td>
<td>BSSAP Cause</td>
<td>Section 23.7.35</td>
</tr>
<tr>
<td>0x65</td>
<td>Session Management Cause</td>
<td>Section 23.7.36</td>
</tr>
</tbody>
</table>

23.7.18 Empty field

This is used for flags, if and only if this IE is present, the flag is set. The semantics depend on the IEI and the context.

```
0  4  8
PDP type IEI Res
Length (0)
```

23.7.19 IMSI

The IMSI is encoded like in octet 4-N of the Called Party BCD Number defined in 3GPP TS 24.008, 10.5.4.7.

```
0  4  8
PDP type IEI Res
Length of IE content
Digit 1 Digit 2
Digit ... Digit N
see Note
```

Note

Either 1 1 1 1 | Number digit N (N odd) or Number digit N | Number digit N-1 (N even), where N is the number of digits.

23.7.20 ISDN-AddressString / MSISDN / Called Party BCD Number

The MSISDN is encoded as an ISDN-AddressString in 3GPP TS 09.02 and Called Party BCD Number in 3GPP TS 24.008. It will be stored by the SGSN or VLR and then passed as is to the GGSN during the activation of the primary PDP Context.
23.7.21 Access Point Name

This encodes the Access Point Name of a PDP Context. The encoding is defined in 3GPP TS 23.003.

23.7.22 Quality of Service Subscribed Service

This encodes the subscribed QoS of a subscriber. It will be used by the SGSN during the PDP Context activation. If the length of the QoS data is 3 (three) octets it is assumed that these are octets 3-5 of the TS 3GPP TS 24.008 Quality of Service Octets. If it is more than three then it is assumed that the first octet is the Allocation/Retention Priority and the rest are encoded as octets 3-N of 24.008.

23.7.23 PDP-Charging Characteristics

This encodes the ChargingCharacteristics of 3GPP TS 32.215. A HLR may send this as part of the InsertSubscriberData or within a single PDP context definition. If the HLR supplies this information it must be used by the SGSN or VLR when activating a PDP context.
23.7.24 Protocol Configuration Options (PCO)

This encodes the Protocol Configuration Options (PCO) of 3GPP TS 29.060 clause 7.7.31, which are the same as those specified in 3GPP TS 24.008 10.5.6.3. It will be used by the ePDG during the PDP Context activation.

23.7.25 HLR Number encoded as 3GPP TS 09.02 ISDN-AddressString

The HLR Number is encoded as an ISDN-AddressString in 3GPP TS 09.02. It will be stored by the SGSN or VLR can be used by the CDR module to keep a record.

![Protocol Configuration Options (PCO) Diagram]

23.7.26 Cause

This IE shall be encoded according to the GMM Cause as described in Chapter 10.5.5.14 of 3GPP TS 24.008.

23.7.27 Supplementary Service Info

This IE shall be used together with both Section 23.8.2 and Section 23.8.1 IEs. It is used to carry the payload of Supplementary Services encoded according to GSM TS 04.80.

23.7.28 IMEI

The IMEI encoded as Called Party BCD Number in 3GPP TS 24.008.

23.7.29 IMEI Check Result

Result of the Check IMEI request. A NACK could be sent in theory, if the ME is not permitted on the network (e.g. because it is on a blacklist).

Table 14: IMEI Check Result

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td>ACK</td>
</tr>
<tr>
<td>0x02</td>
<td>NACK</td>
</tr>
</tbody>
</table>
23.7.30 Message Class

Indicate, which kind of message is being sent. This allows to trivially dispatch incoming GSUP messages to the right code paths, and should make writing a GSUP to MAP converter easier.

This IE was introduced together with inter-MSC handover code. Inter-MSC messages must include this IE and set it to the appropriate type. The intention of creating this IE was to use it with all GSUP messages eventually.

<table>
<thead>
<tr>
<th>Type</th>
<th>Always present</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no</td>
<td>Subscriber Management</td>
</tr>
<tr>
<td>2</td>
<td>no</td>
<td>SMS</td>
</tr>
<tr>
<td>3</td>
<td>no</td>
<td>USSD</td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
<td>Inter-MSC</td>
</tr>
</tbody>
</table>

23.7.31 Source Name

When the GSUP server is asked to forward a message between two GSUP clients, the source name is the IPA name of the client where the message is coming from. The source name IE is present, when the GSUP server forwards the message to the destination. Although redundant, the source name IE is also sent from the source to the GSUP server (so it is easier to follow the network traces).

Source and destination names are sent as nul-terminated strings.

Source: A, Destination: B

Figure 34: Message forwarding example

23.7.32 Destination Name

The receiving counterpart to source name (Section 23.7.31).

23.7.33 AN-APDU

This IE encodes the AN-APDU parameter described in 3GPP TS 29.002 7.6.9.1.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td>BSSAP</td>
</tr>
<tr>
<td>0x02</td>
<td>RANAP</td>
</tr>
</tbody>
</table>
23.7.34 RR Cause

This IE contains the reason for release or completion of an assignment or handover. See 3GPP TS 44.018 10.5.2.31 for reference.

23.7.35 BSSAP Cause

This IE indicates why an event is happening on the BSSAP interface. See 3GPP TS 48.008 3.2.2.5 for reference.

23.7.36 Session Management Cause

This IE contains the reason for rejecting a session management request. See 3GPP TS 24.008 10.5.6.6 / Table 10.5.157 for reference.

23.8 Session (transaction) management

Unlike TCAP/MAP, GSUP is just a transport layer without the dialogue/context. All communication is usually happening over a single connection. In order to fill this gap, there is a few optional IEs, which allow both communication sides to establish and terminate TCAP-like transactions over GSUP.

23.8.1 Session ID

This auxiliary IE shall be used together with Section 23.8.2. The purpose of this IE is to identify a particular transaction using the 4-byte unique identifier.

23.8.2 Session State

This auxiliary IE shall be used together with Section 23.8.1. The purpose of this IE is to indicate a state of a particular transaction, i.e. initiate, continue or terminate it.

Table 16: Session state

<table>
<thead>
<tr>
<th>State</th>
<th>TCAP alternative</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>Undefined</td>
<td>Used when session management is not required</td>
</tr>
<tr>
<td>0x01</td>
<td>BEGIN</td>
<td>Used to initiate a new session</td>
</tr>
<tr>
<td>0x02</td>
<td>CONTINUE</td>
<td>Used to continue an existing session</td>
</tr>
<tr>
<td>0x03</td>
<td>END</td>
<td>Used to terminate an existing session</td>
</tr>
</tbody>
</table>
23.8.3 SM-RP-MR (Message Reference)

According to TS GSM 04.11, section 8.2.3, every single message on the SM-RL (SM Relay Layer) has a unique message reference, that is used to link an RP-ACK or RP-ERROR message to the associated (preceding) RP-DATA or RP-SMMA message transfer attempt.

In case of TCAP/MAP, this message reference is being mapped to the Invoke ID. But since GSUP has no Invoke ID IE, and it is not required for other applications (other than SMS), a special Section 23.8.3 is used to carry the message reference value ’as-is’ (i.e. in range 0 through 255).

23.8.4 SM-RP-DA (Destination Address)

This IE represents the destination address used by the short message service relay sub-layer protocol. It can be one of the following:

- IMSI (see 3GPP TS 29.002, clause 7.6.2.1);
- MSISDN (see 3GPP TS 29.002, clause 7.6.2.17);
- service centre address (see 3GPP TS 29.002, clause 7.6.2.27).

Coding of this IE is described in Section 23.8.6. See 3GPP TS 29.002, section 7.6.8.1 for details.

23.8.5 SM-RP-OA (Originating Address)

This IE represents the originating address used by the short message service relay sub-layer protocol. It can be either of the following:

- MSISDN (see 3GPP TS 29.002, clause 7.6.2.17);
- service centre address (see 3GPP TS 29.002, clause 7.6.2.27).

Coding of this IE is described in Section 23.8.6. See 3GPP TS 29.002, section 7.6.8.2 for details.

23.8.6 Coding of SM-RP-DA / SM-RP-OA IEs

Basically, both Section 23.8.4 / Section 23.8.5 IEs contain a single TV of the following format:

<table>
<thead>
<tr>
<th>Field</th>
<th>Presence</th>
<th>Length</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>M</td>
<td>1</td>
<td>Identity type</td>
</tr>
<tr>
<td>V</td>
<td>O</td>
<td>1</td>
<td>ToN/NPI header</td>
</tr>
<tr>
<td>V</td>
<td>O</td>
<td>...</td>
<td>BCD encoded (or alphanumeric) identity</td>
</tr>
</tbody>
</table>

where the identity type can be one of the following:
Table 18: Identity types of SM-RP-DA / SM-RP-OA IEs

<table>
<thead>
<tr>
<th>Type</th>
<th>ToN/NPI Header</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td>No</td>
<td>IMSI (see 3GPP TS 29.002, clause 7.6.2.1)</td>
</tr>
<tr>
<td>0x02</td>
<td>Yes</td>
<td>MSISDN (see 3GPP TS 29.002, clause 7.6.2.17)</td>
</tr>
<tr>
<td>0x03</td>
<td>Yes</td>
<td>Service centre address (see 3GPP TS 29.002, clause 7.6.2.27)</td>
</tr>
<tr>
<td>0xff</td>
<td>No</td>
<td>Omit value for noSM-RP-DA and noSM-RP-OA</td>
</tr>
</tbody>
</table>

Coding of the optional ToN/NPI header, as well as all possible ToN/NPI values, is described in 3GPP TS 129.002, section 17.7.8 “Common data types”, and can be summarized as follows:

![ToN/NPI header coding](image)

Figure 35: ToN/NPI header coding (as per 3GPP TS 129.002, MSB first)

Please note that unlike both Section 23.7.19 and Section 23.7.20, where the value part is encoded as LV (i.e. contains an additional length), an identity in both Section 23.8.4 / Section 23.8.5 IEs shall not contain the redundant length octet.

23.8.7 SM-RP-UI (SM TPDU)

This IE represents the user data field carried by the short message service relay sub-layer (i.e. SM-TL (Transfer Layer)) protocol. In case of errors (i.e. MO-/MT-forwardSM Error messages), this IE may contain optional diagnostic field payload from RP-ERROR message.

See 3GPP TS 29.002, section 7.6.8.4 for details.

23.8.8 SM-RP-Cause (RP Cause value)

According to TS GSM 04.11, *RP-Cause* is a variable length element always included in the RP-ERROR message, conveying a negative result of an RP-DATA message transfer attempt or RP-SMMA notification attempt.

The mapping between error causes in TS GSM 04.11 and TS GSM 09.02 (MAP) is specified in TS GSM 03.40. But since GSUP has no generic User Error IE, and it is not required for other applications (other than SMS), a special Section 23.8.8 is used to carry the cause value 'as-is'.

23.8.9 SM-RP-MMS (More Messages to Send)

This is an optional IE of MT-ForwardSM-Req message, that is used by SMSC to indicate that there are more MT SMS messages to be sent, so the network should keep the RAN connection open. See 3GPP TS 29.002, section 7.6.8.7.
23.8.10 SM Alert Reason

According to 3GPP TS 29.002, section 7.6.8.8, Alert Reason is used to indicate the reason why the service centre is alerted, e.g. the MS has got some memory to store previously rejected incoming SMS.

It can take one of the following values:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td>MS present</td>
</tr>
<tr>
<td>0x02</td>
<td>Memory Available</td>
</tr>
</tbody>
</table>

Table 19: SM Alert Reason values

24 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.

24.1 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 🟢
```

🟢 Configure process to use SCHED_RR policy with real time priority 1

24.2 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 🟢
```

🟢 Configure process to use cpusched with real time priority 1
Allow main thread (the one managing the VTY) only on CPU 0

Or otherwise:

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

Allow all threads only on CPU 0

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

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

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

```plaintext
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**

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

Allow thread named `TxLower (338635)` only on CPU 1

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

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

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

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

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

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

3GPP
3rd Generation Partnership Project

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

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

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

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

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

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

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

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

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

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

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

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

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

BTS
Base Transceiver Station

BSC
Base Station Controller

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

BVCI
BSSGP Virtual Circuit Identifier

CBC
Cell Broadcast Centre; central entity of Cell Broadcast service

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

CBS
Cell Broadcast Service

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

CC
Call Control; Part of the GSM Layer 3 Protocol

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

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

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

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

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

dB
deci-Bel; relative logarithmic unit

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

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

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

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

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

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

EGPRS
Enhanced GPRS; the part of EDGE relating to GPRS services
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIR</td>
<td>Equipment Identity Register; core network element that stores and manages IMEI numbers</td>
</tr>
<tr>
<td>ESME</td>
<td>External SMS Entity; an external application interfacing with a SMSC over SMPP</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunications Standardization Institute</td>
</tr>
<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array; programmable digital logic hardware</td>
</tr>
<tr>
<td>Gb</td>
<td>Interface between PCU and SGSN in GPRS/EDGE network; uses NS, BSSGP, LLC</td>
</tr>
<tr>
<td>GERAN</td>
<td>GPRS/EDGE Radio Access Network</td>
</tr>
<tr>
<td>GFDL</td>
<td>GNU Free Documentation License; a copyleft-style Documentation License</td>
</tr>
<tr>
<td>GGSN</td>
<td>GPRS Gateway Support Node; gateway between GPRS and external (IP) network</td>
</tr>
<tr>
<td>GMSK</td>
<td>Gaussian Minimum Shift Keying; modulation used for GSM and GPRS</td>
</tr>
<tr>
<td>GPL</td>
<td>GNU General Public License, a copyleft-style Free Software License</td>
</tr>
<tr>
<td>Gp</td>
<td>Gp interface between SGSN and GGSN; uses GTP protocol</td>
</tr>
<tr>
<td>GPRS</td>
<td>General Packet Radio Service; the packet switched 2G technology</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System; provides a highly accurate clock reference besides the global position</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile Communications. ETSI/3GPP Standard of a 2G digital cellular network</td>
</tr>
<tr>
<td>GSMTAP</td>
<td>GSM tap; pseudo standard for encapsulating GSM protocol layers over UDP/IP for analysis</td>
</tr>
<tr>
<td>GSUP</td>
<td>Generic Subscriber Update Protocol. Osmocom-specific alternative to TCAP/MAP</td>
</tr>
<tr>
<td>GT</td>
<td>Global Title; an address in SCCP</td>
</tr>
<tr>
<td>GTP</td>
<td>GPRS Tunnel Protocol; used between SGSN and GGSN</td>
</tr>
<tr>
<td>HLR</td>
<td>Home Location Register; central subscriber database of a GSM network</td>
</tr>
<tr>
<td>HNB-GW</td>
<td>Home NodeB Gateway. Entity between femtocells (Home NodeB) and CN in 3G/UMTS.</td>
</tr>
<tr>
<td>HPLMN</td>
<td>Home PLMN; the network that has issued the subscriber SIM and has his record in HLR</td>
</tr>
<tr>
<td>IE</td>
<td>Information Element</td>
</tr>
</tbody>
</table>
IMEI
International Mobile Equipment Identity; unique 14-digit decimal number to globally identify a mobile device, optionally with a 15th checksum digit

IMEISV
IMEI software version; unique 14-digit decimal number to globally identify a mobile device (same as IMEI) plus two software version digits (total digits: 16)

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

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

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

Iu
Interface in 3G/UMTS between RAN and CN

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

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

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

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

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

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

Location Area
Location Area; a geographic area containing multiple BTS

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

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

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

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

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

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

MGW
Media Gateway
MM
Mobility Management; part of the GSM Layer 3 Protocol

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

MNCC
Mobile Network Call Control; Unix domain socket based Interface between MSC and external call control entity like osmo-sip-connector

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

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

MS
Mobile Station; a mobile phone / GSM Modem

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

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

MSISDN
Mobile Subscriber ISDN Number; telephone number of the subscriber

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

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

MVNO
Mobile Virtual Network Operator; Operator without physical radio network

NCC
Network Color Code; assigned by national regulator

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

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

NSEI
NS Entity Identifier

NVCI
NS Virtual Circuit Identifier

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

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

OCXO
Oven Controlled Crystal Oscillator; very high precision oscillator, superior to a VCTCXO
OML
Operation & Maintenance Link (ETSI/3GPP TS 52.021 [3gpp-ts-52-021])

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

OpenGGSN
Open Source implementation of a GPRS Packet Control Unit

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

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

OsmoBSC
Open Source implementation of a GSM Base Station Controller

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

OsmoSGSN
Open Source implementation of a Serving GPRS Support Node

OsmoPCU
Open Source implementation of a GPRS Packet Control Unit

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

PC
Point Code; an address in MTP

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

PCP
Priority Code Point (IEEE 802.1Q [?])

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

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

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

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

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

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

RACH
Random Access Channel on uplink Um interface; used by MS to request establishment of a dedicated channel
RAM
Remote Application Management; Ability to remotely manage (install, remove) Java Applications on SIM/USIM Card

RF
Radio Frequency

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

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

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

RR
Radio Resources; Part of the GSM Layer 3 Protocol

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

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

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

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

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

SDK
Software Development Kit

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

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

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

SIM
Subscriber Identity Module; small chip card storing subscriber identity

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

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

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

SS
Signaling System No. 7; Classic digital telephony signaling system

SS
Supplementary Services; query and set various service parameters between subscriber and core network (e.g., USSD, 3rd-party calls, hold/retrieve, advice-of-charge, call deflection)
SSH
Secure Shell; IETF RFC 4250 [ietf-rfc4251] to 4254

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

STP
Signaling Transfer Point; A Router in SS7 Networks

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

syslog
System logging service of UNIX-like operating systems

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

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

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

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

TOS
Type Of Service; bit-field in IPv4 header, now re-used as DSCP (IETF RFC 791 [ietf-rfc791])

TRX
Transceiver; element of a BTS serving a single carrier

TS
Technical Specification

u-Boot
Boot loader used in various embedded systems

UBI
An MTD wear leveling system to deal with NAND flash in Linux

UBL
Initial bootloader loaded by the TI Davinci SoC

UDP
User Datagram Protocol (IETF RFC 768 [ietf-rfc768])

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

Um interface
U mobile; Radio interface between MS and BTS

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

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

USSD
Unstructured Supplementary Service Data; textual dialog between subscriber and core network, e.g. *100 → Your extension is 1234
VAMOS
Voice services over Adaptive Multi-user channels on One Slot; an optional extension for GSM specified in Release 9 of 3GPP GERAN specifications (3GPP TS 48.018 [3gpp-ts-48-018]) allowing two independent UEs to transmit and receive simultaneously on traffic channels

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

VLAN
Virtual LAN in the context of Ethernet (IEEE 802.1Q [ieee-802.1q])

VLR
Visitor Location Register; volatile storage of attached subscribers in the MSC

VPLMN
Visited PLMN; the network in which the subscriber is currently registered; may differ from HPLMN when on roaming

VTY
Virtual TeletYpe; a textual command-line interface for configuration and introspection, e.g. the OsmoBSC configuration file as well as its telnet link on port 4242

A Osmocom TCP/UDP Port Numbers

The Osmocom GSM system utilizes a variety of TCP/IP based protocols. The table below provides a reference as to which port numbers are used by which protocol / interface.

<table>
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<tr>
<th>L4 Protocol</th>
<th>Port Number</th>
<th>Purpose</th>
<th>Software</th>
</tr>
</thead>
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<td>osmo-mgw, osmo-bts</td>
</tr>
<tr>
<td>UDP</td>
<td>2427</td>
<td>MGCP GW</td>
<td>osmo-bsc_mgcp, osmo-mgw</td>
</tr>
<tr>
<td>TCP</td>
<td>2775</td>
<td>SMPP (SM interface for external programs)</td>
<td>osmo-nitb</td>
</tr>
<tr>
<td>TCP</td>
<td>3002</td>
<td>A-bis/IP OML</td>
<td>osmo-bts, osmo-bsc, osmo-nitb</td>
</tr>
<tr>
<td>TCP</td>
<td>3003</td>
<td>A-bis/IP RSL</td>
<td>osmo-bts, osmo-bsc, osmo-nitb</td>
</tr>
<tr>
<td>TCP</td>
<td>4227</td>
<td>telnet (VTY)</td>
<td>osmo-pcap-client</td>
</tr>
<tr>
<td>TCP</td>
<td>4228</td>
<td>telnet (VTY)</td>
<td>osmo-pcap-server</td>
</tr>
<tr>
<td>TCP</td>
<td>4236</td>
<td>Control Interface</td>
<td>osmo-trx</td>
</tr>
<tr>
<td>TCP</td>
<td>4237</td>
<td>telnet (VTY)</td>
<td>osmo-trx</td>
</tr>
<tr>
<td>TCP</td>
<td>4238</td>
<td>Control Interface</td>
<td>osmo-bts</td>
</tr>
<tr>
<td>TCP</td>
<td>4239</td>
<td>telnet (VTY)</td>
<td>osmo-stp</td>
</tr>
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<td>TCP</td>
<td>4240</td>
<td>telnet (VTY)</td>
<td>osmo-pcu</td>
</tr>
<tr>
<td>TCP</td>
<td>4241</td>
<td>telnet (VTY)</td>
<td>osmo-bts</td>
</tr>
<tr>
<td>TCP</td>
<td>4242</td>
<td>telnet (VTY)</td>
<td>osmo-nitb, osmo-bsc, cellmgr-ng</td>
</tr>
<tr>
<td>TCP</td>
<td>4243</td>
<td>telnet (VTY)</td>
<td>osmo-bsc_mgcp, osmo-mgw</td>
</tr>
<tr>
<td>TCP</td>
<td>4244</td>
<td>telnet (VTY)</td>
<td>osmo-bsc_nat</td>
</tr>
<tr>
<td>TCP</td>
<td>4245</td>
<td>telnet (VTY)</td>
<td>osmo-sgsn</td>
</tr>
<tr>
<td>TCP</td>
<td>4246</td>
<td>telnet (VTY)</td>
<td>osmo-gbproxy</td>
</tr>
<tr>
<td>TCP</td>
<td>4247</td>
<td>telnet (VTY)</td>
<td>OsmocomBB</td>
</tr>
<tr>
<td>TCP</td>
<td>4249</td>
<td>Control Interface</td>
<td>osmo-nitb, osmo-bsc</td>
</tr>
<tr>
<td>TCP</td>
<td>4250</td>
<td>Control Interface</td>
<td>osmo-bsc_nat</td>
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<td>TCP</td>
<td>4251</td>
<td>Control Interface</td>
<td>osmo-sgsn</td>
</tr>
<tr>
<td>TCP</td>
<td>4252</td>
<td>telnet (VTY)</td>
<td>symobts-mgr</td>
</tr>
<tr>
<td>TCP</td>
<td>4253</td>
<td>telnet (VTY)</td>
<td>osmo-gtphub</td>
</tr>
<tr>
<td>TCP</td>
<td>4254</td>
<td>telnet (VTY)</td>
<td>osmo-msc</td>
</tr>
<tr>
<td>L4 Protocol</td>
<td>Port Number</td>
<td>Purpose</td>
<td>Software</td>
</tr>
<tr>
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<td>----------------------------</td>
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<tr>
<td>TCP</td>
<td>4255</td>
<td>Control Interface</td>
<td>osmo-msc</td>
</tr>
<tr>
<td>TCP</td>
<td>4256</td>
<td>telnet (VTY)</td>
<td>osmo-sip-connector</td>
</tr>
<tr>
<td>TCP</td>
<td>4257</td>
<td>Control Interface</td>
<td>osmo-ggsn, ggsn (OpenGGSN)</td>
</tr>
<tr>
<td>TCP</td>
<td>4258</td>
<td>telnet (VTY)</td>
<td>osmo-hlr</td>
</tr>
<tr>
<td>TCP</td>
<td>4259</td>
<td>Control Interface</td>
<td>osmo-hlr</td>
</tr>
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<td>TCP</td>
<td>4260</td>
<td>telnet (VTY)</td>
<td>osmo-ggsn</td>
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<td>TCP</td>
<td>4261</td>
<td>telnet (VTY)</td>
<td>osmo-hnbgw</td>
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<tr>
<td>TCP</td>
<td>4262</td>
<td>Control Interface</td>
<td>osmo-hnbgw</td>
</tr>
<tr>
<td>TCP</td>
<td>4263</td>
<td>telnet (VTY)</td>
<td>osmo-gbproxy</td>
</tr>
<tr>
<td>TCP</td>
<td>4264</td>
<td>telnet (VTY)</td>
<td>osmo-cbc</td>
</tr>
<tr>
<td>TCP</td>
<td>4265</td>
<td>Control Interface</td>
<td>osmo-cbc</td>
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<tr>
<td>TCP</td>
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<td>osmo-hlr</td>
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<td>osmo-ngw</td>
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<td>TCP</td>
<td>4268</td>
<td>telnet (VTY)</td>
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<tr>
<td>SCTP</td>
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<td>UECUPS</td>
<td>osmo-uecups</td>
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<td>TCP</td>
<td>4269</td>
<td>telnet (VTY)</td>
<td>osmo-e1d</td>
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<td>TCP</td>
<td>4270</td>
<td>telnet (VTY)</td>
<td>osmo-isdntap</td>
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<tr>
<td>TCP</td>
<td>4271</td>
<td>telnet (VTY)</td>
<td>osmo-smlc</td>
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<tr>
<td>TCP</td>
<td>4272</td>
<td>Control Interface</td>
<td>osmo-smlc</td>
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<tr>
<td>TCP</td>
<td>4273</td>
<td>telnet (VTY)</td>
<td>osmo-hnodeb</td>
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<tr>
<td>TCP</td>
<td>4274</td>
<td>Control Interface</td>
<td>osmo-hnodeb</td>
</tr>
<tr>
<td>TCP</td>
<td>4275</td>
<td>telnet (VTY)</td>
<td>osmo-upf</td>
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<tr>
<td>TCP</td>
<td>4276</td>
<td>Control Interface</td>
<td>osmo-upf</td>
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<tr>
<td>TCP</td>
<td>4277</td>
<td>telnet (VTY)</td>
<td>osmo-pfcp-tool</td>
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<tr>
<td>TCP</td>
<td>4278</td>
<td>Control Interface</td>
<td>osmo-pfcp-tool</td>
</tr>
<tr>
<td>UDP</td>
<td>4729</td>
<td>GSMTAP</td>
<td>Almost every osmocom project</td>
</tr>
<tr>
<td>TCP</td>
<td>5000</td>
<td>A/IP</td>
<td>osmo-bsc, osmo-bsc_nat</td>
</tr>
<tr>
<td>UDP</td>
<td>23000</td>
<td>GPRS-NS over IP default port</td>
<td>osmo-pcu, osmo-sgsn, osmo-gbproxy</td>
</tr>
<tr>
<td>TCP</td>
<td>48049</td>
<td>BSC-CBC (CBS) default port</td>
<td>osmo-bsc, osmo-cbc</td>
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### Bibliography / References

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

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


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

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


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

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

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

[53] [3gpp-ts-45-002] 3GPP TS 45.002: General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN) interface; Network service https://www.3gpp.org/DynaReport/45002.htm

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


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


[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


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


[87] [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


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

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