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osmo-remsim User Manual

by Harald Welte

DRAFT

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HISTORY			
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1 Overview

1.1 About this manual

This manual should help you getting started with the osmo-remsim software.

It will cover aspects of configuration and running osmo-remsim as well as some introduction about its internal architecture and external interfaces.

1.2 About osmo-remsim

osmo-remsim is a suite of software programs enabling physical/geographic separation of a cellular phone (or modem) on the one hand side and the SIM/USIM/ISIM card on the other side.

Using osmo-remsim, you can operate an entire fleet of modems/phones, as well as banks of SIM cards and dynamically establish or remove the connections between modems/phones and cards.

So in technical terms, it behaves like a proxy for the ISO 7816 smart card interface between the MS/UE and the UICC/SIM/USIM/ISIM.

While originally designed to be used in context of cellular networks, there is nothing cellular specific in the system. It can therefore also be used with other systems that use contact based smart cards according to ISO 7816. Currently only the T=0 protocol with standard (non-extended) APDUs is supported. Both T=1 and extended APDU support can easily be added as a pure software update, should it be required at some future point.

1.3 Credits

osmo-remsim was originally developed by Harald Welte with contributions by Kevin Redon. It builds on top of pre-existing infrastructure of the Osmocom project, including the Osmocom SIMtrace project.

Development of osmo-remsim software was funded by GSMK and sysmocom.

1.4 osmo-remsim-server

The `osmo-remsim-server` is the central element of the osmo-remsim architecture. All other elements connect to it. It maintains the inventory of other network elements, as well as the list of slot-mappings, i.e. the relationship between each given physical card in a bank and each card emulator attached to a phone/modem.

The tasks of `osmo-remsim-server` include:

- accepting incoming TCP control connections from `osmo-remsim-client` and `osmo-remsim-bankd` instances
- providing a RESTful JSON interface for external application logic to

For more information, please see Section 2.

1.5 osmo-remsim-client

The `osmo-remsim-client` software is co-located next to the *user of the card* which traditionally is a phone or modem. However, there are other flavors of clients available, too. This is for example useful if existing software wants to interface remote smart cards, rather than those physically inserted into a local reader next to the PC running that application.

In the classic phone / modem use case, osmo-remsim-client typically runs on an [embedded] computer next to the phone/modem.

The tasks of `osmo-remsim-client` include:

- interaction with the user application. For phone/modem, that's over USB with a device supported by the *SIMtrace2 cardem* firmware, which provides the physical interface to the phone/modem SIM interface (ISO 7816-3).

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- establishing a TCP connection with the osmo-remsim-server, in order to enable the server to issue control commands
- under control of osmo-remsim-server, establishing a TCP connection to a osmo-remsim-bankd in order to connect a card physically located at the bankd.

osmo-remsim-client supports at this point only one phone/modem. If you have multiple phones/modems at one location, you can simply run multiple instances of osmo-remsim-client on the same system, one for each phone/modem.

For more information, please see [?].

1.6 osmo-remsim-bankd

The osmo-remsim-bankd software is co-located next to a bank of SIM cards.

The tasks of osmo-remsim-bankd include:

- interaction with the actual card reader hardware. At this point, only PC/SC based readers are supported, with 1 to 255 slots per reader.
- establishing a TCP connection with the osmo-remsim-server, in order to enable the server to issue control commands
- running a TCP server where TCP connections from osmo-remsim-client instances are accepted and handled.

For more information, please see Section 7.

1.7 osmo-remsim-apitool

The osmo-remsim-apitool utility is an optional tool that can be used to manually interface with the RSRES interface of osmo-remsim-server in absence of a back-end system managing this.

For more information, please see Section 3.

1.8 RSPRO

RSPRO is the *R*emote *S*IM *PRO*tocol. It is a binary protocol specified in ASN.1 which is spoken on any of the internal connections between osmo-remsim-client, osmo-remsim-bankd and osmo-remsim-server.

You can find more information about RSPRO in Section 9.

1.9 RSRES

RSRES is the *R*emote *S*IM *RES*T protocol. It is an interface offered by osmo-remsim-server towards external back-end application logic of the operator of an osmo-remsim network.

You can find more information about RSRES in Section 2.3.

1.10 Security

Warning
RSPRO, RSRES and their underlying transport layer both operate in plain-text, There is no authentication or encryption built into the protocol. It is assumed that the protocols are only spoken over trusted, controlled IP networks, such as inside a VPN or a closed / private corporate network.

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2 osmo-remsim-server

2.1 Running

`osmo-remsim-server` currently has no command-line arguments. It will bind to INADDR_ANY and offer the following TCP ports:

- Port 9998 for the inbound control connections from `osmo-remsim-client` and `osmo-remsim-bankd`
- Port 9997 for the RESTful/JSON Web API (role: HTTP server)

It is intended to make these settings (IP addresses, ports) configurable in future versions.

2.1.1 SYNOPSIS

osmo-remsim-server [-h] [-V] [-d LOGOPT]

2.1.2 OPTIONS

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

-V, --version
Print the software version number

-d, --debug LOGOPT
Configure the logging verbosity, see Section 8.

2.2 Logging

`osmo-remsim-server` currently logs to stderr only; the logging verbosity is configurable via command line argument only. However, as the libosmocore logging framework is used, extending this is an easy modification.

2.3 RESTful/JSON Web API

`osmo-remsim-server` provides a RESTful/JSON WEB API for application logic integration. The purpose of the API is to allow run-time configuration and monitoring of the entire osmo-remsim system.

The API currently has version 1, and the URL prefix is /api/backend/v1

Warning
The RESTful/JSON Web API operates in plain-text, There is no authentication or encryption built into the protocol. It is assumed that the protocol is only spoken over trusted, controlled IP networks, such as inside a VPN or a closed / private corporate network.

2.3.1 /api/backend/v1/clients

GET obtains a JSON list where each element represents one currently connected `osmo-remsim-client`.

No other HTTP operation is implemented.

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2.3.2 /api/backend/v1/clients/:client_id

GET obtains a single JSON object representing one specific currently connected `osmo-remsim-client`.

No other HTTP operation is implemented.

2.3.3 /api/backend/v1/banks

GET obtains a JSON list where each element represents one currently connected `osmo-remsim-bankd`.

No other HTTP operation is implemented.

2.3.4 /api/backend/v1/banks/:bank_id

GET obtains a single JSON object representing one specific currently connected `osmo-remsim-bankd`.

No other HTTP operation is implemented.

2.3.5 /api/backend/v1/slotmaps

GET obtains a JSON list where each element represents one provisioned slot mapping.

POST creates a new slot mapping as specified in the JSON syntax contained in the HTTP body.

No other HTTP operation is implemented.

2.3.6 /api/backend/v1/slotmaps/:slotmap_id

DELETE deletes a slot mapping by its identifier. If the mapping is currently in use, the related bankd is instructed to disconnect the client from the card.

No other HTTP operation is implemented.

2.3.7 /api/backend/v1/global-reset

POST performs a global reset of the `osmo-remsim-server` state. This means all mappings are removed.

2.3.8 Examples

remsim-server is on 10.2.3.4, one simbank with 5 cards: http://10.2.3.4:9997/api/backend/v1/banks


```
{"banks":[{"peer":"B1","state":"CONNECTED_BANKD","component_id":{"type_":"remsimBankd"," ↩
    name":"fixme-name","software":"remsim-bankd","swVersion":"0.1.0.17-6d8a"},"bankId":1," ↩
    numberOfSlots":5}]}
```


remsim-server is on 10.2.3.4, 4 clients: http://10.2.3.4:9997/api/backend/v1/clients


```
{"clients":[{"peer":"C0:2","state":"CONNECTED_CLIENT","component_id":{"type_":"remsimClient ↩
    ","name":"simtrace2-remsim-client","software":"remsim-client","swVersion":"0.1.0.17-6d8a ↩
    "}},{"peer":"C0:0","state":"CONNECTED_CLIENT","component_id":{"type_":"remsimClient"," ↩
    name":"simtrace2-remsim-client","software":"remsim-client","swVersion":"0.1.0.17-6d8a ↩
    "}},{"peer":"C0:3","state":"CONNECTED_CLIENT","component_id":{"type_":"remsimClient"," ↩
    name":"simtrace2-remsim-client","software":"remsim-client","swVersion":"0.1.0.17-6d8a ↩
    "}},{"peer":"C0:1","state":"CONNECTED_CLIENT","component_id":{"type_":"remsimClient"," ↩
    name":"simtrace2-remsim-client","software":"remsim-client","swVersion":"0.1.0.17-6d8a ↩
    "}}]}
```


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3 osmo-remsim-apitool

`osmo-remsim-apitool` is a small python script whic can be used to manually control `osmo-remsim-server` via its RESTful interface in setups where no external back-end application is controlling this interface.

For more information about The RESTful inteface, see [?].

3.1 Usage

Common command line arguments that can be used with any of the commands below:

-H, --host HOST
Specify the hostname / IP of the `osmo-remsim-server` to connect to. Default: localhost

-P, --port PORT
Specify the remote TCP port of the RSRES interface of `osmo-remsim-server`. Default: 9997 **-v, --verbose** Increase verbosity of output: Show the GET request generated, not just the response.

3.1.1 Listing connected clients

The command `osmo-remsim-apitool -c` can be used to list all currently connected clients.

```
$ osmo-remsim-apitool -c
/clients: {'clients': [{'peer': 'C23:0', 'state': 'CONNECTED_CLIENT', 'component_id': {' ↩
    type_': 'remsimClient', 'name': 'nataraja', 'software': 'remsim-client', 'swVersion':  ↩
    '0.2.2.63-844b'}}]}
```

3.1.2 Listing connected bankds

The command `osmo-remsim-apitool -b` can be used to list all currently connected bankds.

```
$ osmo-remsim-apitool -b
/banks: {'banks': [{'peer': 'B1', 'state': 'CONNECTED_BANKD', 'component_id': {'type_': ' ↩
    remsimBankd', 'name': 'fixme-name', 'software': 'remsim-bankd', 'swVersion':  ↩
    '0.2.2.46-3598'}, 'bankId': 1, 'numberOfSlots': 5}]}
```

3.1.3 Listing installed slotmaps

The command `osmo-remsim-apitool -s` can be used to list all currently installed slotmaps.

```
$ osmo-remsim-apitool -s
/slotmaps: {'slotmaps': [{'bank': {'bankId': 1, 'slotNr': 1}, 'client': {'clientId': 23, ' ↩
    slotNr': 0}, 'state': 'ACTIVE'}]}
```

3.1.4 Listing all information

The command `osmo-remsim-apitool -a` can be used to list all information (clients, bankds, slotmaps).

```
$ osmo-remsim-apitool -a
/clients: {'clients': [{'peer': 'C23:0', 'state': 'CONNECTED_CLIENT', 'component_id': {' ↩
    type_': 'remsimClient', 'name': 'nataraja', 'software': 'remsim-client', 'swVersion':  ↩
    '0.2.2.63-844b'}}]}
/banks: {'banks': [{'peer': 'B1', 'state': 'CONNECTED_BANKD', 'component_id': {'type_': ' ↩
    remsimBankd', 'name': 'fixme-name', 'software': 'remsim-bankd', 'swVersion':  ↩
    '0.2.2.46-3598'}, 'bankId': 1, 'numberOfSlots': 5}]}
/slotmaps: {'slotmaps': [{'bank': {'bankId': 1, 'slotNr': 1}, 'client': {'clientId': 23, ' ↩
    slotNr': 0}, 'state': 'ACTIVE'}]}
```

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3.1.5 Creating a slotmap

The command `osmo-remsim-apitool -m bank_id bankd_slot client_id client_slot` can be used to create a new slotmap.

Create a slotmap between Bankd 1 Slot a (B1:1) and Client 23 Slot 0 (C23:0)

```
$ osmo-remsim-apitool -m 1 1 23 0
```

3.1.6 Deleting a slotmap

The command `osmo-remsim-apitool -d bank_id bank_slot` can be used to create a new slotmap.

Remove a slotmap for Bankd 1 Slot a (B1:1)

```
$ osmo-remsim-apitool -m 1 1
```

3.1.7 Reset all state

The command `osmo-remsim-apitool -r` can be used to reset all state in bankd, including all slotmaps.

```
$ osmo-remsim-apitool -r
```

Warning
Use with extreme caution, particularly in production environments.

4 osmo-remsim-client-st2

The client interfaces with GSM phones / modems via dedicated "Card Emulation" devices such as the Osmocom SIMtrace2 or sysmocom sysmoQMOD board + firmware. This hardware implements the ISO7816-3 electrical interface and protocol handling and passes any TPDU headers received from the phone/modem to `osmo-remsim-client` for further processing of the TPDUs associated to the given APDU transfer.

`osmo-remsim-client` connects via a RSPRO control connection to `osmo-remsim-server` at startup and registers itself. It will receive configuration data such as the `osmo-remsim-bankd` IP+Port and the ClientId from `osmo-remsim-server`.

After receiving the configuration, `osmo-remsim-client` will establish a RSPRO data connection to the `osmo-remsim-bankd` IP:Port.

As the USB interface for remote SIM in simtrace2.git uses one interface per slot, we can implement the client in blocking mode, i.e. use blocking I/O on the TCP/RSPRO side. This simplifies the code compared to a more complex async implementation.

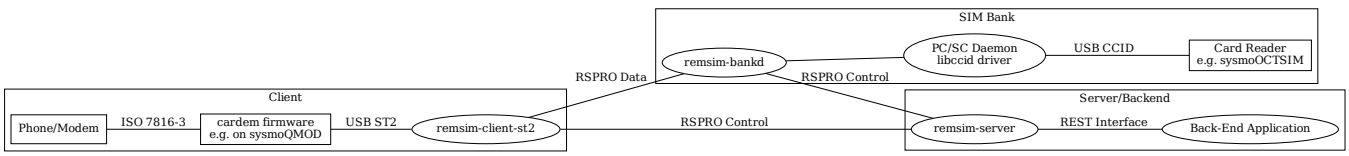

Figure 1: Overall osmo-remsim architecture using osmo-remsim-client-st2

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4.1 Running

osmo-remsim-client-st2 currently has the following command-line options:

4.1.1 SYNOPSIS

osmo-remsim-client-st2 [. . .]

4.1.2 OPTIONS

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

-V, --version
Print the software version number

-d, --debug LOGOPT
Configure the logging verbosity, see Section 8.

-i, --server-ip A.B.C.D
Specify the remote IP address / hostname of the `osmo-remsim-server` to which this client shall establish its RSPRO control connection

-p, --server-port <1-65535>
Specify the remote TCP port number of the `osmo-remsim-server` to which this client shall establish its RSPRO control connection

-c, --client-id <1-1023>
Specify the numeric client identifier of the SIM bank this bankd instance operates. The tuple of client-id and client-slot must be unique among all clients connecting to the same `osmo-remsim-server`.

-n, --client-slot <0-1023>
Specify the slot number served within this client. The tuple of client-id and client-slot must be unique among all clients connecting to the same `osmo-remsim-server`.

-a, --atr HEXSTRING
Specify the initial ATR to be communicated to the modem/phone. Can and will later be overridden by the ATR as specified by `osmo-remsim-bankd` once a card has been mapped to this client, unless the `--atr-ignore-rspro` option is also specified.

-r, --atr-ignore-rspro
Ignore any incoming RSPRO setAtrReq and always only use the locally-specified ATR when communicating with the UE/modem/phone. This can be used to constrain the capabilities advertised. This way, for example, the baud rate can be constrained, or the use of logical channels prevented.

-e, --event-script COMMAND
Specify the shell command to be execute when the client wants to call its helper script

-V, --usb-vendor
Specify the USB Vendor ID of the USB device served by this client, use e.g. 0x1d50 for SIMtrace2, sysmoQMOD and OWHW.

-P, --usb-product
Specify the USB Product ID of the USB device served by this client, use e.g. 0x4004 for sysmoQMOD.

-C, --usb-config
Specify the USB Cofiguration number of the USB device served by this client. Default will use current configuration of the device.

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-I, --usb-interface
Specify the USB Interface number (within active configuration) of the USB device served by this client. Default will use FIXME.

-S, --usb-altsetting
Specify the USB Alternate Setting to be used within the USB Interface of the USB device served by this client. Default will use FIXME.

-A, --usb-address <0-255>
Specify the USB Address of the USB device served by this client. This is useful in case multiple identical USB devices are attached to the same host. However, the address changed at every re-enumeration and it's therefor recommended to use the USB path (see below).

-H, --usb-path
Specify the USB path of the USB device served by this client. This is usefule to disambiguate between multiple identical USB devices attached to the same host. You don't need this if you have only one SIM emulation device attached to your system.

4.1.3 Examples

remsim-server is on 10.2.3.4, sysmoQMOD on usb bus, all 4 modems:

```
osmo-remsim-client-st2 -s 10.2.3.4 -V 1d50 -P 4004 -C 1 -I 0 -H 2-1.1 -c 0 -n 0
osmo-remsim-client-st2 -s 10.2.3.4 -V 1d50 -P 4004 -C 1 -I 1 -H 2-1.1 -c 0 -n 1
osmo-remsim-client-st2 -s 10.2.3.4 -V 1d50 -P 4004 -C 1 -I 0 -H 2-1.4 -c 0 -n 2
osmo-remsim-client-st2 -s 10.2.3.4 -V 1d50 -P 4004 -C 1 -I 1 -H 2-1.4 -c 0 -n 3
```

4.2 Logging

`osmo-remsim-client` currently logs to stdout only, and the logging verbosity is not yet configurable. However, as the libosmocore logging framework is used, extending this is an easy modification.

4.3 Helper Script

`osmo-remsim-client` can call an external shell command / script / program at specific instances of time. This serves two purposes:

- To keep external system integration posted about the overall status of remsim-client, such as whether or not it is connected to a server and/or bankd.
- To request the external system to perform specific actions, such as triggering the reset of the modem - in case the hardware doesn't allow the simtrace2 firmware to do that itself.

4.3.1 Script Environment Variables

The environment passed to the helper script contains a number of variables to provide inormation to the external script:

Table 1: Environment Variables

Name	Example Value	Description
REMSIM_CLIENT_VERSION	0.2.2.37-5406a	Compile version of the software
REMSIM_SERVER_ADDR	1.2.3.4:1234	Address and port of the remsim-server
REMSIM_SERVER_STATE	CONNECTED	FSM state of the connection to remsim-server
REMSIM_BANKD_ADDR	1.2.3.4:1234	Address and port of the remsim-bankd
REMSIM_BANKD_STATE	CONNECTED	FSM state of the connection to remsim-bankd

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Table 1: (continued)

Name	Example Value	Description
REMSIM_CLIENT_SLOT	23:42	Client ID and Client Slot Number
REMSIM_BANKD_SLOT	55:33	Bank ID and Bank Slot Number
REMSIM_USB_PATH	2-1.1	USB path of the USB device with simtrace2 cardem firmware
REMSIM_USB_INTERFACE	1	Interface number of the USB device with simtrace2 cardem firmware
REMSIM_SIM_VCC	1	Whether or not the modem currently applies SIM VCC (0/1)
REMSIM_SIM_RST	1	Whether or not the modem currently asserts SIM RST (0=inactive, 1=active)
REMSIM_CAUSE	request-card-insert	The cause why this script has been called

4.3.2 REMSIM_CAUSE values

The REMSIM_CAUSE environment variable (as well as the first argument) passed to the helper script indicated why the script has been called.

Name	Description
event-modem-status	The SIM card interface status has changed (e.g. VCC/RST change)
event-bankd-connect	A logical RSPRO connection to a bankd has been established
event-server-connect	A logical RSPRO connection to a server has been established
event-config-bankd	The server has instructed the client of the bankd address
request-card-insert	The client asks the system to simulate SIM card insertion to the modem
request-card-remove	The client asks the system to simulate SIM card removal from the modem
request-sim-remote	The client asks the system to switch to remote SIM
request-sim-local	The client asks the system to switch to local SIM
request-modem-reset	The client asks the system to perform a modem reset

5 osmo-remsim-client-shell

This is a remsim-client that's mostly useful for manual debugging/testing or automatic testing.

Instead of using hardware like the SIMtrace with cardem firmware to interface a virtual SIM card to a real phone or modem, it simply offers and interactive way to exchange APDUs with a remote SIM card via STDIO of the process.

This allows testing of large parts of the osmo-remsim-client code as well as the integration with the overall osmo-remsim network including osmo-remsim-server, osmo-remsim-bankd and any external backend application driving the REST interface.

5.1 Running

osmo-remsim-client-shell currently has the following command-line options:

5.1.1 SYNOPSIS

osmo-remsim-client-shell [. . .]

5.1.2 OPTIONS

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

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-v, --version
Print the compile-time version information

-d, --debug LOGOPT
Configure the logging verbosity, see Section 8.

-i, --server-ip A.B.C.D
Specify the remote IP address / hostname of the `osmo-remsim-server` to which this client shall establish its RSPRO control connection

-p, --server-port <1-65535>
Specify the remote TCP port number of the `osmo-remsim-server` to which this client shall establish its RSPRO control connection

-c, --client-id <1-1023>
Specify the numeric client identifier of the SIM bank this bankd instance operates. The tuple of client-id and client-slot must be unique among all clients connecting to the same `osmo-remsim-server`.

-n, --client-slot <0-1023>
Specify the slot number served within this client. The tuple of client-id and client-slot must be unique among all clients connecting to the same `osmo-remsim-server`. `osmo-remsim-bankd` once a card has been mapped to this client.

-e, --event-script COMMAND
Specify the shell command to be execute when the client wants to call its helper script

5.1.3 Examples

The below example uses stderr-redirection to avoid the log output cluttering the console.

remsim-server is at 192.168.11.10; we are client 23 slot 0

```
./osmo-remsim-client-shell -i 192.168.11.10 -c 23  2>/dev/null
SET_ATR: 3b 00
SET_ATR: 3b 7d 94 00 00 55 55 53 0a 74 86 93 0b 24 7c 4d 54 68
a0a40000023f00
R-APDU: 9f 17
```

- The first SET_ATR is performed by osmo-remsim-client locally using a default ATR
- The second SET_ATR is performed by osmo-remsim-bankd to inform us about the ATR of the real remote card
- The `a0a40000023f00` is a command TPDU entered on STDIN by the suer
- The `9f17` is a response TPDU provided by the remote card in response to the command

The program continues in this loop (read command APDU as hex-dump from stdin; provide response on stdout) until it is terminated by Ctrl+C or by other means.

6 libifd_remsim_client

This is a remsim-client implemented as so-called `ifd_handler`, i.e. a card reader driver that plugs into the bottom side of the PC/SC daemon of pcsc-lite.

Using this library, you can use normal smart card application programs with remote smart cards managed by osmo-remsim. The setup looks like this:

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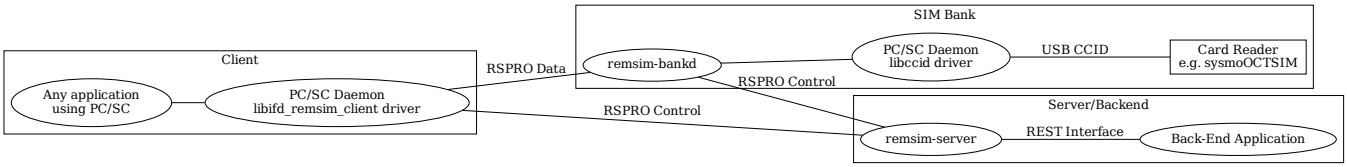

Figure 2: Overall osmo-remsim architecture using libifd_remsim_client

6.1 Configuration

Like all non-USB PC/SC reader drivers, this is happening in `/etc/reader.conf` or, at least on Debian GNU/Linux based systems via files in `/etc/reader.conf.d`. The osmo-remsim software includes an example configuration file and installs it as `osmo-remsim-client-reader_conf` in that directory.

contents of the configuration example provided by osmo-remsim-client

```
#FRIENDLYNAME "osmo-remsim-client"
#DEVICENAME   0:0:192.168.11.10:9998
#LIBPATH /usr/lib/pcsc/drivers/libifd-osmo-remsim-client.bundle/Contents/Linux/ ↩
    libifd_remsim_client.so
```

As you can see, all lines are commented out by default. In order to enable the remsim-client virtual reader, you need to

- remove the # character on all three lines
- configure the DEVICNAME according to your local configuration. It is a string with fields separated by colons, in the form of CLIENT_ID:CLIENT_SLOT:SERVER_IP:SERVER_PORRT
  - First part is the Client ID (default: 0)
  - Second part is the Client SlotNumbera (default: 0)
  - Third part is the IP address of the `osmo-resim-server` (default: localhost)
  - Last part is the RSPRO TCP port of the `osmo-remsim-server` (default: 9998)

Once the configuration file has been updated, you should re-start pcscd by issuing `systemctl restart pcscd` or whatever command your Linux distribution uses for restarting services.

You can check if the driver is loaded by using the `pcsc_scan` tool included with `pcscd`:

```
$ pcsc_scan
Using reader plug'n play mechanism
Scanning present readers...
0: osmo-remsim-client 00 00

Wed Mar  4 13:31:42 2020
 Reader 0: osmo-remsim-client 00 00
  Event number: 0
  Card state: Card removed,
 _
```

Once a proper slotmap to an existing SIM card in a remote bank daemon has been installed in the server, you should see something like this:

```
$ pcsc_scan
Using reader plug'n play mechanism
Scanning present readers...
0: osmo-remsim-client 00 00
```

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```
Wed Mar  4 13:35:18 2020
 Reader 0: osmo-remsim-client 00 00
  Event number: 1
  Card state: Card inserted,
  ATR: 3B 7D 94 00 00 55 55 53 0A 74 86 93 0B 24 7C 4D 54 68

ATR: 3B 7D 94 00 00 55 55 53 0A 74 86 93 0B 24 7C 4D 54 68
+ TS = 3B --> Direct Convention
+ T0 = 7D, Y(1): 0111, K: 13 (historical bytes)
  TA(1) = 94 --> Fi=512, Di=8, 64 cycles/ETU
    62500 bits/s at 4 MHz, fMax for Fi = 5 MHz => 78125 bits/s
  TB(1) = 00 --> VPP is not electrically connected
  TC(1) = 00 --> Extra guard time: 0
+ Historical bytes: 55 55 53 0A 74 86 93 0B 24 7C 4D 54 68
  Category indicator byte: 55 (proprietary format)

Possibly identified card (using /home/laforge/.cache/smartcard_list.txt):
        NONE
```

From now on, you can use any application using PC/SC, whether C, Python or Java with a remote SIM card managed by osmo-remsim.

7 osmo-remsim-bankd

The `osmo-remsim-bankd` (SIM Bank Daemon) manages one given SIM bank. The initial implementation supports a PC/SC driver to expose any PC/SC compatible card readers as SIM bank.

`osmo-remsim-bankd` initially connects via a RSPRO control connection to `osmo-remsim-server` at startup, and will in turn receive a set of initial [client,slot]:[bankd,slot] mappings. These mappings determine which slot on the client (corresponding to a modem) is mapped to which slot on the SIM bank. Mappings can be updated by `osmo-remsim-server` at any given point in time.

`osmo-remsim-bankd` implements a RSPRO server, where it listens to connections from `osmo-remsim-clients`.

As PC/SC only offers a blocking API, there is one thread per PC/SC slot. This thread will perform blocking I/O on the socket towards the client, and blocking API calls on PC/SC.

In terms of thread handling, we do:

- accept() handling in [spare] worker threads
  - this means blocking I/O can be used, as each worker thread only has one TCP connection
  - client identifies itself with client:slot
  - lookup mapping based on client:slot (using mutex for protection)
  - open the reader based on the lookup result

The worker threads initially don't have any mapping to a specific reader, and that mapping is only established at a later point after the client has identified itself. The advantage is that the entire bankd can live without any non-blocking I/O.

The main thread handles the connection to `osmo-remsim-server`, where it can also use non-blocking I/O. However, re-connection would be required, to avoid stalling all banks/cards in the event of a connection loss to the server.

worker threads have the following states: * INIT (just started) * ACCEPTING (they're blocking in the accept() call on the server socket fd) * CONNECTED_WAIT_ID (TCP established, but peer not yet identified itself) * CONNECTED_CLIENT (TCP established, client has identified itself, no mapping) * CONNECTED_CLIENT_MAPPED (TCP established, client has identified itself, mapping exists) * CONNECTED_CLIENT_MAPPED_CARD (TCP established, client identified, mapping exists, card opened) * CONNECTED_SERVER (TCP established, server has identified itself)

Once the client disconnects, or any other error occurs (such as card I/O errors), the worker thread either returns to INIT state (closing client socket and reader), or it terminates. Termination would mean that the main thread would have to do non-blocking join to detect client termination and then re-spawn clients, so the "return to INIT state" approach seems to make more sense.

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7.1 Running

`osmo-remsim-bankd` currently has the following command-line options:

7.1.1 SYNOPSIS

osmo-remsim-bankd [-h] [-V] [-d LOGOPT] -i A.B.C.D [-p <1-65535>] [-b <1-1023>] [-n <1-1023>] [-I A.B.C.D] [-P <1-65535>]

7.1.2 OPTIONS

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

-V, --version
Print the software version number

-d, --debug LOGOPT
Configure the logging verbosity, see Section 8.

-i, --server-host A.B.C.D
Specify the remote IP address/hostname of the `osmo-remsim-server` to which this bankd shall establish its RSPRO control connection. Do not specify a loopback address or localhost, as this would in most cases result in a broken configuration where a [usually remote] remsim-client attempts to reach the bankd via loopback, which doesn't work.

-p, --server-port <1-65535>
Specify the remote TCP port number of the `osmo-remsim-server` to which this bankd shall establish its RSPRO control connection

-b, --bank-id <1-1023>
Specify the numeric bank identifier of the SIM bank this bankd instance operates. Must be unique among all banks connecting to the same `osmo-remsim-server`.

-n, --num-slots <1-1023>
Specify the number of slots that this bankd handles.

-I, --bind-IP A.B.C.D
Specify the local IP address to which the socket for incoming connections from `osmo-remsim-clients` is bound to.

-P, --bind-port <1-65535>
Specify the local TCP port to which the socket for incoming connections from `osmo-remsim-client`s is bound to.

-s, --permit-shared-pcsc
Specify whether the PC/SC readers should be accessed in SCARD_SHARE_SHARED mode, instead of the default (SCARD_SHARE_EXCLUSIVE). Shared mode would permit multiple application programs to access a single reader/slot/card concurrently. This is potentially dangerous as the two programs operate without knowledge of each other, and either of them might modify the card state (such as the currently selected file, validated PIN, etc.) in a way not expected by the other application.

-g, --gsmtap-ip A.B.C.D
Enable GSMTAP and send APDU traces to given IP.

-G, --gsmtap-slot <0-1023>
Limit tracing to given bank slot, only (default: all slots).

-L, --disable-color
Disable colors for logging to stderr.

-T, --timestamp
Prefix every log line with a timestamp.

-e, --log-level number
Set a global loglevel for all logging.

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7.1.3 Examples

remsim-server is on 10.2.3.4, cardreader has 5 slots:

```
osmo-remsim-bankd -i 10.2.3.4 -n 5
```

remsim-server is on 10.2.3.4, cardreader has 4 slots, local ip is 10.5.4.3

```
osmo-remsim-bankd -i 10.2.3.4 -n 4 -I 10.5.4.3
```

7.2 Logging

`osmo-remsim-bankd` currently logs to stdout only, and the logging verbosity is not yet configurable. However, as the libosmocore logging framework is used, extending this is an easy modification.

7.3 `bankd_pcsc_slots.csv` CSV file

bankd expects a CSV file `bankd_pcsc_slots.csv` in the current working directory at startup.

This CSV file specifies the mapping between the string names of the PCSC readers and the RSPRO bandk/slot numbers. The format is as follows:

- first column: bankd number
- second column: slot number within bankd
- third column: extended POSIX regular expression matching the slot

Example: CSV file mapping bankd slots 0..4 to an ACS ACR33U-A1 reader slots

```
"1","0","ACS ACR33 ICC Reader 00 00"
"1","1","ACS ACR33 ICC Reader 00 01"
"1","2","ACS ACR33 ICC Reader 00 02"
"1","3","ACS ACR33 ICC Reader 00 03"
"1","4","ACS ACR33 ICC Reader 00 04"
```

You can obtain the exact string to use as PC/SC reader name from the output of the `pcsc_scan` utility (part of pcsc-lite package). The tool will produce output like:

Example: Output of pcsc_scan utility on a system with a single reader installed

```
Scanning present readers...
0: Alcor Micro AU9560 00 00
```

In this example, there's only a single PC/SC reader available, and it has a string of "Alcor Micro AU9560 00 00" which needs to be used in the CSV file.

NOTE

If the reader name contains any special characters, they might need to be escaped according to the extended POSIX regular expression syntax. See `man 7 regex` for a reference.

Example: CSV file mapping bankd slots 0..7 to a sysmoOCTSIM:

```
"1","0","sysmocom sysmoOCTSIM \[CCID\] \(ab19180f3335355320202034463a15ff\) [0-9]{2} 00"
"1","1","sysmocom sysmoOCTSIM \[CCID\] \(ab19180f3335355320202034463a15ff\) [0-9]{2} 01"
"1","2","sysmocom sysmoOCTSIM \[CCID\] \(ab19180f3335355320202034463a15ff\) [0-9]{2} 02"
"1","3","sysmocom sysmoOCTSIM \[CCID\] \(ab19180f3335355320202034463a15ff\) [0-9]{2} 03"
"1","4","sysmocom sysmoOCTSIM \[CCID\] \(ab19180f3335355320202034463a15ff\) [0-9]{2} 04"
"1","5","sysmocom sysmoOCTSIM \[CCID\] \(ab19180f3335355320202034463a15ff\) [0-9]{2} 05"
"1","6","sysmocom sysmoOCTSIM \[CCID\] \(ab19180f3335355320202034463a15ff\) [0-9]{2} 06"
"1","7","sysmocom sysmoOCTSIM \[CCID\] \(ab19180f3335355320202034463a15ff\) [0-9]{2} 07"
```

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In the above example, the \[CCID\] and the \(serialnumber\) both had to be escaped.

The [0-9]{2} construct exists to perform wildcard matching, no matter which particular two-digit number pcscd decides to use.

Example: CSV file mapping bankd slot 0 to a OMNIKEY 3x21 Smart Card Reader:

```
"1","0","HID Global OMNIKEY 3x21 Smart Card Reader \[OMNIKEY 3x21 Smart Card Reader\] 00 ↩
    00"
```

8 osmo-remsim logging

All programs within the osmo-remsim project use the logging sub-system of libosmocore.

Contrary to the larger Osmocom projects with their own VTY + configuration file, the logging configuration for osmo-remsim programs must happen via command line arguments.

Also, contrary to the larger Osmocom projects, only logging to stderr is supported; no direct logging to log files, syslog, systemd, etc. is supported at this point.

8.1 -d command line argument

Every osmo-remsim program like osmo-remsim-bankd, osmo-remsim-server or osmo-remsim-client-st2 supports a -d command line argument. This argument takes one mandatory parameter configuring the log level for each log sub-system as follows:

```
-d SUBSYS,num_lvl[:SUBSYS,num_lvl[:...]]
```

So basically, a colon-separated list of tuples, where each tuple contains the sub-system name and the *numeric* log level.

Below is the list of sub-systems and a table of numerical levels:

Table 2: libosmocore log levels and their numeric values

Level name	Numeric value
DEBUG	1
INFO	3
NOTICE	5
ERROR	7
FATAL	8

Table 3: osmo-remsim log sub-system names and their description

Sub-System Name	Description
DMAIN	respective main program code
DST2	SIMtrace2 cardem firmware interaction via USB
DRSPRO	RSPRO protocol between bankd, server and client
DREST	REST interface of osmo-remsim-server

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Table 3: (continued)

Sub-System Name	Description
DSLOTMAP	slotmap code shared by `osmo-remsim-server` and `osmo-remsim-bankd`
DBANKDW	worker threads of `osmo-remsim-bankd`

8.2 Example

Putting the above in a concrete example:

`-d DMAIN,5:DRSPRO,1`

would perform the following configuration:

- log only NOTICE (or higher) messages in the DMAIN subsystem (low verbosity)
- log DEBUG (or higher) messages in the DRSPRO subsystem (very high verbosity)

9 RSPRO

RSPRO, the **Remote SIM Protocol**, is an osmo-remsim specific, non-standard communications protocol used between the elements of the osmo-remsim system.

It is specified in ASN.1 syntax (see `asn1/RSPRO.asn` in the `osmo-remsim` source code) and uses BER (Basic Encoding Rules) on the transport level.

Warning
RSPRO and its underlying transport layer both operate in plain-text, There is no authentication or encryption built into the protocol. It is assumed that the protocol is only spoken over trusted, controlled IP networks, such as inside a VPN or a closed / private corporate network.

9.1 Underlying Transport Layer

RSPRO uses TCP as an underlying transport protocol. As TCP doesn't preserve message boundaries, the IPA multiplex is used as intermediate layer between TCP and the BER-encoded RSPRO PDU.

For more information about the IPA multiplex, see the related chapter in http://ftp.osmocom.org/docs/latest/osmobts-abis.pdf

RSPRO uses the IPA CCM PING/PONG messages for keep-alive and detection of dead/stale connections. The compiled-in defaults transmits one IPA PING every 30s and waits 10s for a response from the peer before declaring the connection as dead.

9.2 RSPRO PDU

An RsproPDU consists of:

- **version** of the protocol (v2 is current)
- **tag** specified by the sender, echoed back by the receiver in its response so the server can map responses back to a specific request
- **msg** the actual RSPRO Message (union/choice)

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9.3 RSPRO Operations

Each RSPRO Operation typically (unless specified othewise) consists of a Request and Response pair.

9.3.1 ConnectBank

This is used by `remsim-bankd` to identify itself to `remsim-server` and to establish a logical connection between the two elements.

9.3.2 ConnectClient

This is used by `remsim-client` to identify itself to `remsim-server` and to establish a logical connection between the two elements.

9.3.3 CreateMapping

This is used by `remsim-server` to install a slot mapping in a `remsim-bankd`.

9.3.4 RemoveMapping

This is used by `remsim-server` to remove a slot mapping from a `remsim-bankd`.

9.3.5 ConfigClientId

This is used by `remsim-server` to dynamically configure a ClientID in a `remsim-client`. This mode is currently not supported yet, each client must have a locally-configured ClientID.

9.3.6 ConfigClientBank

This is used by `remsim-server` to inform a `remsim-client` about the details (bankd ID, slot number, IP address, TCP port) of a the `remsim-bankd` to which it shall connect.

9.3.7 ErrorInd

This is a generic error indication that can be sent by any RSRPO entity.

9.3.8 SetAtr

This is used by `remsim-bankd` to inform the `remsim-client` about the ATR of the card, so that `remsim-client` can replicate that ATR when answering to the reset of the SIM card interface of the phone/modem.

9.3.9 TpduModemToCard

This is used by `remsim-client` to transfer a command TPDU/APDU from the phone/modem to the SIM card in `remsim-bankd`

9.3.10 TpduCardToModem

This is used by `remsim-bankd` to transfer a response TPDU/APDU from the SIM card back to the phone/modem at `remsim-client`

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9.3.11 ClientSlotStatusInd

This is used by `remsim-client` to report the status of a given slot.

9.3.12 BankSlotStatusInd

This is used by `remsim-bankd` to report the status of a given slot.

10 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

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

BTS
Base Transceiver Station

BSC
Base Station Controller

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

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

BVCI
BSSGP Virtual Circuit Identifier

CBC
Cell Broadcast Centre; central entity of Cell Broadcast service

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

CBS
Cell Broadcast Service

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

CC
Call Control; Part of the GSM Layer 3 Protocol

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

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

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

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

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

dB
deci-Bel; relative logarithmic unit

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

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

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

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

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DSP
Digital Signal Processor

dvnixload
Tool to program UBL and the Bootloader on a sysmoBTS

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

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

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

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

ETSI
European Telecommunications Standardization Institute

FPGA
Field Programmable Gate Array; programmable digital logic hardware

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

GERAN
GPRS/EDGE Radio Access Network

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

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

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

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

Gp
Gp interface between SGSN and GGSN; uses GTP protocol

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

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

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

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

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

GT
Global Title; an address in SCCP

GTP
GPRS Tunnel Protocol; used between SGSN and GGSN

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

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

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

IE
Information Element

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

IMEISV
IMEI software version; unique 14-digit decimal number to globally identify a mobile device (same as IMEI) plus two software version digits (total digits: 16)

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

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

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

Iu
Interface in 3G/UMTS between RAN and CN

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

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

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

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

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

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

Location Area
Location Area; a geographic area containing multiple BTS

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

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

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

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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

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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

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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

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

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

SS7
Signaling System No. 7; Classic digital telephony signaling system

SS
Supplementary Services; query and set various service parameters between subscriber and core network (e.g. USSD, 3rd-party calls, hold/retrieve, advice-of-charge, call deflection)

SSH
Secure Shell; *IETF RFC 4250* [ietf-rfc4251] to 4254

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

STP
Signaling Transfer Point; A Router in SS7 Networks

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

syslog
System logging service of UNIX-like operating systems

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

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

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

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

TOS
Type Of Service; bit-field in IPv4 header, now re-used as DSCP (*IETF RFC 791* [ietf-rfc791])

TRX
Transceiver; element of a BTS serving a single carrier

TS
Technical Specification

u-Boot
Boot loader used in various embedded systems

UBI
An MTD wear leveling system to deal with NAND flash in Linux

UBL
Initial bootloader loaded by the TI Davinci SoC

UDP
User Datagram Protocol (*IETF RFC 768* [ietf-rfc768])

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

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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 Bibliography / References

A.0.0.0.1 References

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

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

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

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

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

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

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

Copyright © 2019-2021 sysmocom - s.f.m.c. GmbH

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Copyright © 2019-2021 sysmocom - s.f.m.c. GmbH

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Copyright © 2019-2021 sysmocom - s.f.m.c. GmbH

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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