

RaveModemFactory
Software architecture
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ChangeLog

Date	Version	Changes
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2016-06-29	5	Update for RaveModemFactory 1.26: <ul style="list-style-type: none">Updated sections 1.2 Components and 3.1 Startup with information about how the TCP/IP based support works.Added section 4.3.1, Library initialization API to specify how to select between local or TCP/IP based operations.
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1. Introduction

The RaveModemFactory is a **connection manager** that allows to use 3GPP mobile broadband modems (e.g. GSM, HSPA, or LTE) implementing the **Qualcomm MSM Interface (QMI)** protocol. This protocol will be available in modems with Qualcomm Gobi 3G/4G chipsets, like e.g.:

- Sierra Wireless 9200 family (MC7700, MC7710...)
- Sierra Wireless 9x15 family (MC7304, MC7330, MC7354...)
- Sierra Wireless 9x30 family (MC7430, MC7455...)

3GPP2 technologies (e.g. CDMA or EV-DO) are not currently supported.

The RaveModemFactory system provides a **simple** and **stateless** interface to the basic operations that can be performed with a mobile broadband modem.

One of the major advantages of the system is that the user does not need to know which kind of modem is connected to the system, or which interfaces are exposed, or how to control those interfaces. The RaveModemFactory will work with every QMI-capable modem, regardless of manufacturer or version.

The user application will just need to use the RaveModemFactory interfaces to fully interact with the modem, as well as to get a fully established Internet connection.

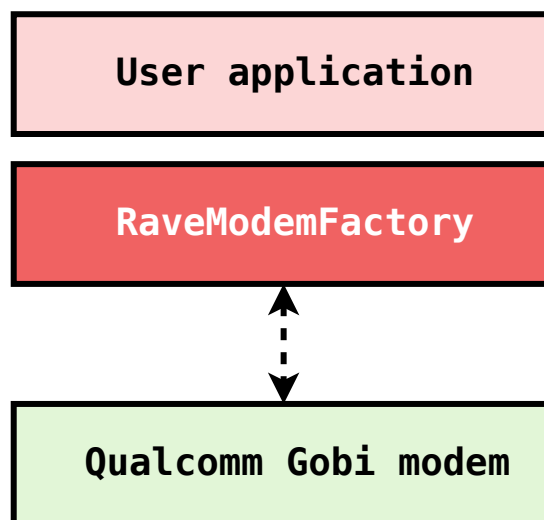


Illustration 1: High level architecture

1.1. Dependencies

The RaveModemFactory software is based on several system level tools, including:

- **Linux kernel** with the `cdc-wdm` (since Linux 2.6.26) and `qmi_wwan`¹ (since Linux 3.4) drivers. Support for the Sierra Wireless 9x30 family (MC74xx devices) only since Linux 4.5.
- The **Glib/GIO**² (>= 2.32) libraries. These libraries are the core foundation libraries of the GNOME project, and provide a general-purpose set of tools for C-based applications.

1 <https://sigquit.wordpress.com/2014/06/11/qmiwwan-or-gobinet/>

2 <https://developer.gnome.org/gio/stable/>

- The **GUdev**³ (>= 147) library. This library provides a Glib/GIO based interface to use the udev⁴ device manager (e.g. for automatic device discovery).
- The **libqmi**⁵ (>= 1.6.2) library. This library exposes a simple Glib/GIO based asynchronous interface to use the QMI protocol with the modem. Along with the library, a `qmicli` tool will also be available, which allows to use the QMI protocol directly from command line.
- The **iproute2**⁶ tools to manage network interfaces.
- The ISC **dhclient**⁷ DHCP client daemon.

1.2. Components

The RaveModemFactory system is itself built as 3 different components:

- The **rmfd** system daemon, developed in C using the Glib/GIO library, which takes care of the actual control of the modem (including network interface and routing rules setup).
- The **librmf** library, developed in C++, which provides a simple interface for the actions available through the `rmfd` daemon. The communication between the `rmfd` daemon and the `librmf` library is done either through a standard Unix socket⁸ or through a TCP/IP socket.
- The **rmfcli** tool, developed in C++, which provides a command line interface for all the operations exposed by the `librmf` shared library.

Although the command line interface is a fully functional tool, applications wanting to use the RaveModemFactory are expected to link to the shared `librmf` library.

3 <http://www.freedesktop.org/software/systemd/gudev/>

4 <http://en.wikipedia.org/wiki/Udev>

5 <https://sigquit.wordpress.com/2012/08/20/an-introduction-to-libqmi/>

6 <http://en.wikipedia.org/wiki/Iproute2>

7 <https://www.isc.org/downloads/dhcp/>

8 The unix socket is by default exposed at `/tmp/rmfd-server`.

2. Architecture

The following diagram depicts a typical setup of the RaveModemFactory components and how they interact with the other system tools. The user application in the diagram will use the shared `librmf` library interfaces to control the modem and gather status information from it.

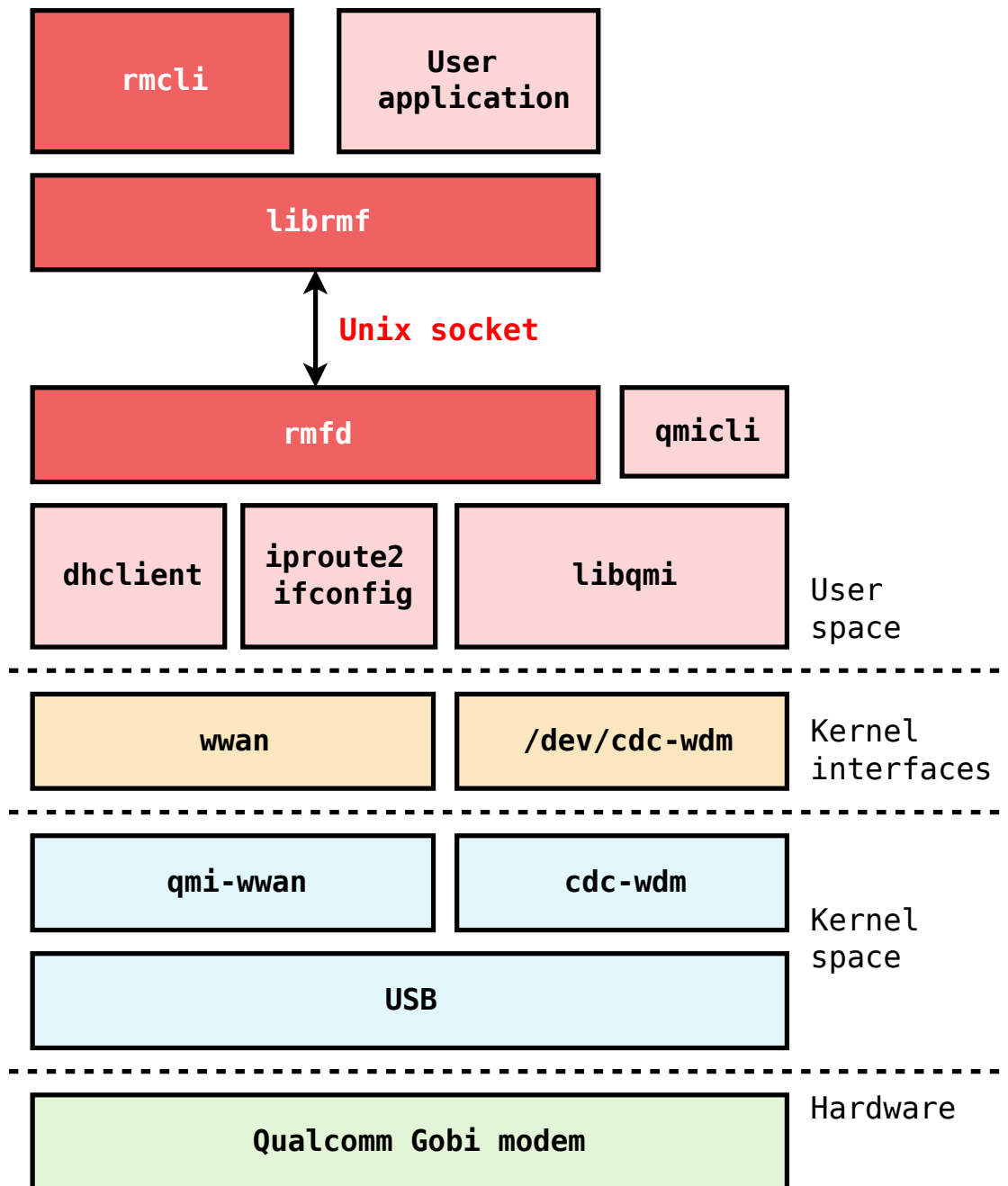


Illustration 2: Low-level architecture

The blocks in the diagram are organized by color as follows:

- Dark red: the RaveModemFactory components.
- Light red: other userspace programs and libraries.
- Orange: the modem interfaces exposed by the kernel.
- Blue: the kernel and its drivers.
- Green: the modem hardware.

3. Basic operation

3.1. Startup

The `rmfd` daemon is setup as a **system daemon** that should be automatically launched as any other service in the system (e.g. via init scripts or `systemd` service units). In the same way, the daemon should be shutdown when the system is going to be halted.

If no additional option is given when launching the `rmfd` daemon, it will listen by default in the local **UNIX socket**. For the **TCP/IP** based operation the daemon expects these additional options:

```
Usage: rmfd <option>

Application Options:
-y, --address=[IP]      IP address where to enable the TCP listener
-Y, --port=[PORT]      Port where to enable the TCP listener
```

3.2. Device discovery

The **kernel** is in charge of detecting the Qualcomm Gobi modem via its **USB 2.0** subsystem. Once the USB device is detected and configured, the `qmi-wwan` and `cdc-wdm` kernel drivers will take care of the QMI interfaces. For every QMI-capable USB interface, the `qmi-wwan` driver will expose a **wwan** network interface, and the `cdc-wdm` driver will expose an associated `/dev/cdc-wdm` character device.

Once the network and character devices are exposed by the kernel, they will also get notified via the **udev** device manager. The `rmfd` daemon listens to `udev` events, and will therefore automatically discover that a QMI modem is available.

3.3. Device initialization

Before using the mobile broadband modem, the `rmfd` daemon needs to fully initialize the device. Among other things, the following steps will be performed:

- The daemon will make sure that a specific `/dev/cdc-wdm` character device will be used to get a specific `wwan` network connected.
- The QMI protocol will be **reset** so that any previously allocated service clients are disposed.
- Link layer protocol^{9 10}:
 - On kernels before 4.5, the network interface will be explicitly configured to use **802.3** data format as well as no QoS headers.
 - On kernel 4.5 or newer, the network interface will be configured to use the same data format as reported by the modem, either **802.3** or **raw IP**.
- The QMI protocol version information of the device will be preloaded in the QMI stack.
- The daemon will initialize several service-specific **QMI clients**, for the DMS (device management), NAS (network access), UIM (user identity module) and WMS (wireless messaging) services.

9 The default USB configuration in the Sierra Wireless MC73xx modems will expose 2 pairs of `wwan` interfaces, one configured by default to use 802.3 data format, and the other one raw IP packets.

10 The Sierra Wireless MC74xx modems only support raw IP packets.

3.4. SIM management

The RaveModemFactory system allows performing different SIM management¹¹ operations, including SIM-PIN unlocking, enabling/disabling or changing.

The application using the RaveModemFactory system will need to make sure that the SIM-PIN is unlocked before trying to use the modem. The librmf library provides methods to both check if the unlock is necessary, and also to actually send the unlock code to the modem.

The SIM-PIN unlock operation will by default make sure that the SIM is fully initialized before returning the action result to the caller.

3.5. Network registration

Once SIM-PIN has been successfully unlocked, or if SIM-PIN lock was already disabled, the rmfd daemon will automatically request the modem to register in the **home network**. If the home network is not available, the modem will try to register in any roaming network where it's allowed to register. If the automatic registration procedure doesn't get the modem registered in 60s, the daemon will launch an explicit network scan operation to list the available networks, and once the scan is finished, it will restart the automatic registration in the home network.

3.6. Network connection

Once the modem is registered in a network, the user of the RaveModemFactory system will be able to request the modem to get connected to a specific **APN**. If the APN requires authentication, additional username and password parameters can also be given during the connection procedure.

If the connection call doesn't fail, the modem will be reported as connected in the QMI stack. The rmfd daemon will then bring the associated wwan interface **up** (using either ifconfig or iproute2) and will also request the **IP, routing and name resolution** setup via DHCP (using dhclient). The built-in DHCP server in the modem will take care of providing the expected settings to use.

Given that even the DNS resolution configuration is being managed, the rmfd daemon will backup the previous configuration¹² and will restore it whenever the QMI wwan interface gets disconnected.

Routing-wise, the rmfd daemon will take care of the **default route** once the QMI wwan interface gets connected, but will not re-select any other default route when disconnected.

3.7. Network disconnection

Network disconnection can be explicitly requested by the users of the RaveModemFactory system. When disconnected, the wwan network interface will be brought **down**, the DNS resolution configuration will be restored, and the call will be stopped in the QMI stack.

11 Since RaveModemFactory v1.28.0, the SIM management commands are based on the complex "UIM" QMI service, instead of the simpler "DMS" QMI service specific "DMS UIM" commands, as these were obsoleted in the new Sierra Wireless MC74xx devices.

12 /etc/resolv.conf

3.8. SMS messaging

The `rmfd` daemon will by default log to `syslog` all the SMS messages received by the mobile broadband modem, e.g.:

```
jan 12 11:27:03 athena rmfd[12805]: SMS [Timestamp: 150112112700+01] [From: +34639335936] This is the SMS text content
```

The `Timestamp:` field gives the SMS timestamp (YYMMDDhhmmss+utc offset), and the `From:` field indicates the sender number.

3.9. Statistics

The `rmfd` daemon keeps track of the ongoing connection statistics, as well as the monthly accumulated ones.

Each ongoing session is tracked in a stats log file¹³, with a new record written every 10s containing the modem-reported statistics and other state values. Each record contains a list of TAB-separated fields, including:

- **Type of record:** S (start), P (partial) or F (final). When connection is launched, a S record is written, then P records every 10s until a last F record when disconnected in a controlled way.
- **Start timestamp:** Date and Time of when the connection was started. If the time can be retrieved from the modem itself it will be given in ISO8601 format, and otherwise it will include the Unix timestamp of the system.
- **Record timestamp:** Date and Time of when the record was written. If the time can be retrieved from the modem itself it will be given in ISO8601 format, and otherwise it will include the Unix timestamp of the system.
- **Duration:** Duration of the ongoing session, given in seconds.
- **Bytes RX:** Total bytes received, as measured by the modem itself.
- **Bytes TX:** Total bytes transmitted as measured by the modem itself.
- **Radio interface:** Radio interface being used in the connection (e.g. gsm, umts or lte).
- **RSSI:** Received Signal Strength Indication, given in dBm.
- **MCC:** Mobile country code of the serving system.
- **MNC:** Mobile network code of the serving system.
- **LAC:** Location area code of the serving system.
- **CID:** Cell ID of the serving system.

An full example of a single connection session would look like the following:

S	2015-03-19 09:49:56	2015-03-19 09:49:56	0	0	0	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:50:06	10	22591	13816	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:50:16	20	22845	14183	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:50:26	30	22845	14183	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:50:36	40	22845	14426	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:50:46	50	23565	14502	umts	-104	214	3	1140	10774738

¹³ `/var/log/rmfd.stats`

P	2015-03-19 09:49:56	2015-03-19 09:50:56	60	23565	14502	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:51:06	70	23565	14615	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:51:16	80	23565	14615	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:51:26	90	23565	14615	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:51:36	100	23565	14615	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:51:46	110	23721	14735	umts	-95	214	3	1140	10774738
P	2015-03-19 09:49:56	2015-03-19 09:51:56	120	23721	14735	umts	-95	214	3	1140	10774738
F	2015-03-19 09:49:56	2015-03-19 09:52:06	130	23721	14848	umts	-95	214	3	1140	10774738

Once the connection has been fully disconnected, a new log will be written to syslog with the stats accumulated in the session:

```
mar 19 09:52:06 athena rmfd[12805]: Connection stats [from: 2015-03-19 09:49:56,
to: 2015-03-19 09:52:06, duration: 130s] [rx: 23721, tx: 14848] [access tech:
umts, rssi: -95dBm] [mcc: 214, mnc: 3, lac: 1140, cid: 10774738] [month 2015/3
rx: 23721, tx: 14848]
```

In addition to the last connection stats, the monthly accumulated RX/TX stats are also given.

If a connection is abruptly disconnected (e.g. system shuts down), the last valid record in the stats file is considered as the final record of the last connection, even if it's not a F (final) one. When rmfd restarts and detects that such situation happened, it will explicitly log to syslog the message corresponding to the last connection. In order to avoid additional logging to syslog of the same information it will also convert the last record to a F (final) one.

The stats log file is recreated every month. When rmfd detects that a new connection is happening in a month after the last one stored in the stats file, it will issue a new log to syslog before fully removing the stats log file contents:

```
mar 1 01:02:03 athena rmfd[999]: Month stats (2015/2) [rx: 586413, tx: 624682]
```

Assuming approximately 90 bytes per record, in the worst case of an ongoing connection 24/7 during the whole month, the size of the stats file may grow up to ~23MBytes:

```
90 * 6 * 60 * 24 * 31 = 24105600 ~23MB
```

4. librmf

4.1. Overview

The `librmf` library exposes the **Modem C++ namespace**, which includes the methods that allow remotely acting on the `rmfd` daemon. The user of the `librmf` library, doesn't need to know how the communication with the daemon is done.

All the methods implemented in the `librmf` library are **synchronous** and **blocking**. It is expected that if asynchronicity is desired, the user application will take care of e.g. launching these methods in separate threads.

Errors in the `librmf` library methods will throw `std::runtime_error` **exceptions**, including a text string explaining the error that happened.

All the method executions in the `librmf` library are **stateless** and independent to each other. Multiple processes, or even multiple threads in the same process, can run actions in parallel using `librmf`.

By default the `librmf` library assumes that the communication with the `rmfd` daemon will be local through the standard **UNIX socket**. If the `rmfd` daemon is running in a different system and listening in a TCP port on a remote IP address, the client can instruct the library to default to using **TCP/IP** instead.

4.2. Usage

The `librmf` library can be used by including the header file in the sources where you want to use the API methods:

```
#include <rmf-operations.h>
```

And also (assuming it was installed in `/usr`) adding the following arguments during the preprocessing and linking operations:

```
-I/usr/include/librmf    // preprocessing  
-lrmf                   // linking
```

A full simple example of usage is included later in section 4.4.

4.3. API

The following sections show the application programming interface exposed by `librmf`.

4.3.1. Library initialization API

```
bool SetTargetRemote (const std::string address,  
                     uint16_t          port);  
bool SetTargetLocal  (void);
```

Before any other operation is done, the client can specify where the `rmfd` daemon is listening. By default the daemon is expected in the local UNIX socket, so this operation is only strictly needed if the daemon is listening on a remote (or local) TCP port.

The target setting may be changed only if there are no other API commands running.

4.3.2. Device availability API

```
bool IsModemAvailable (void);
```

The user of the librmf library does not need to know which kind of modem is connected to the system, and not even which are the interfaces the modem is exposing. All that information is automatically managed by the rmfd daemon, which will just tell whether a suitable modem is available or not.

If more than one modem is available, or if a modem exposes multiple QMI interfaces, the first configured one will be used. If the modem is available but not ready to work (e.g. SIM card is missing), it will still be flagged as available, but the operations performed with it will end up failing.

4.3.3. Device identification API

```
std::string GetManufacturer (void);  
std::string GetModel (void);  
std::string GetSoftwareRevision (void);  
std::string GetHardwareRevision (void);  
std::string GetImei (void);
```

The RaveModemFactory system allows to query the modem for several device identification strings, including the IMEI¹⁴.

The device identification strings will be retrievable even if the SIM-PIN lock is enabled and locked.

4.3.4. SIM identification API

```
struct PlmnInfo {  
    uint16_t mcc;  
    uint16_t mnc;  
    bool      gsm;  
    bool      umts;  
    bool      lte;  
};  
  
std::string GetImsi (void);  
std::string GetIccid (void);  
void GetSimInfo (uint16_t &operatorMcc,  
                 uint16_t &operatorMnc,  
                 std::vector<struct PlmnInfo> &plmns);
```

The RaveModemFactory system allows to query the modem for several SIM identification strings, including the IMSI¹⁵ and the ICCID¹⁶.

The GetSimInfo method returns not only the MCC/MNC¹⁷ of the network operator which issued the SIM card (as per the EFad¹⁸ SIM file), but also a list of other allowed operators with their access technologies (as per the EFoplmnwact¹⁹ SIM file, if available).

Note that the previous methods may not return valid information until the SIM-PIN has been totally unlocked.

14 http://en.wikipedia.org/wiki/International_Mobile_Station_Equipment_Identity

15 http://en.wikipedia.org/wiki/International_mobile_subscriber_identity

16 http://en.wikipedia.org/wiki/Subscriber_identity_module#ICCID

17 http://en.wikipedia.org/wiki/Mobile_country_code

18 Administrative Data, 3GPP TS 31.121

19 Operator Controlled PLMN Selector with Access Technology, 3GPP TS 31.121

4.3.5. SIM-PIN management API

```
bool IsSimLocked (void);
void Unlock      (const std::string pin);
void EnablePin   (bool enable,
                  const std::string pin);
void ChangePin   (const std::string pin,
                  const std::string newPin);
```

In addition to checking the SIM-PIN status and unlocking it if necessary, the RaveModemFactory system also allows to enable, disable, and change the SIM-PIN lock code.

The `IsSimLocked()` method will return `false` if either the SIM-PIN is fully disabled or if it is enabled but already unlocked through `Unlock()`.

Working with SIM-PUK is not directly available through the `librmf` interfaces. If for any reason the SIM gets locked asking for PUK, the `qmicli` tool can be used to unlock it using `--dms-uim-unblock-pin`.

4.3.6. Power management API

```
enum PowerStatus {
    Full,
    Low
};

PowerStatus GetPowerStatus (void);
void SetPowerStatus (PowerStatus powerStatus);
void PowerCycle      (void);
```

The RaveModemFactory system allows to put the modem into low-power mode (i.e. RF off), and back to full-power mode (i.e. RF on). Obviously, the modem needs to be in full-power mode before it can be registered in the operator network.

If the modem is initially detected in low-power mode, the `rmfd` daemon will not automatically bring it into full-power mode. Additionally, re-setting the Full power status (even if it already is in that status) will trigger a new network scan if the modem is not yet registered to the operator network.

A full modem power cycle can also be requested using the `PowerCycle()` method. In this case, the `rmfd` daemon will reply as soon as the request has been accepted; i.e. it will not wait for the full reboot sequence to finish before replying.

4.3.7. Network registration API

```
enum RegistrationStatus {
    Idle,
    Searching,
    Home,
    Roaming,
    Scanning
};

RegistrationStatus GetRegistrationStatus (std::string &operatorDescription,
                                           uint16_t &operatorMcc,
                                           uint16_t &operatorMnc,
                                           uint16_t &lac,
                                           uint32_t &cid);
void SetRegistrationTimeout (uint32_t timeout);
uint32_t GetRegistrationTimeout (void);
```

The RaveModemFactory has its own automatic logic to get registered in the mobile network. Therefore, librmf only allows checking the registration status, or querying and modifying the registration timeout before the built-in network scan request is launched.

The returned registration info includes not only the MCC/MNC²⁰ of the service provider network, but also the location area code²¹ and cell id²² where the modem is registered, which can be used to locate the position of the device with low accuracy.

4.3.8. Network status API

```
enum RadioInterface {
    Gsm,
    Umts,
    Lte
};

struct RadioPowerInfo {
    RadioInterface radioInterface;
    bool            inTraffic;
    double          txPower;
    bool            rx0RadioTuned;
    double          rx0Power;
    bool            rx1RadioTuned;
    double          rx1Power;
};

struct RadioSignalInfo {
    RadioInterface radioInterface;
    int32_t        rssi;
    uint32_t       quality;
};

std::vector<RadioPowerInfo> GetPowerInfo (void);
std::vector<RadioSignalInfo> GetSignalInfo (void);
```

The GetPowerInfo() method returns an array of structures which specify, per radio interface, whether the TX and RX chains are in traffic and what the power measurement is in each (given in dBm, only if in traffic).

The GetSignalInfo() method returns an array of structures which specify, per radio interface, the quality of the network link. The quality is given both as the measured RSSI²³ (in dBm, where -125dBm or lower indicates no signal) and as a percentage.

4.3.9. Network connection API

```
enum ConnectionStatus {
    Disconnected,
    Disconnecting,
    Connecting,
    Connected
};

ConnectionStatus GetConnectionStatus (void)
void             Connect              (const std::string apn,
```

20 http://en.wikipedia.org/wiki/Mobile_country_code

21 http://en.wikipedia.org/wiki/Mobility_management#Location_area

22 http://en.wikipedia.org/wiki/Cell_ID

23 http://en.wikipedia.org/wiki/Received_signal_strength_indication

		<code>const std::string user,</code>
		<code>const std::string password)</code>
<code>void</code>	Disconnect	<code>(void);</code>
<code>std::string</code>	GetDataPort	<code>(void);</code>

The user of the librmf library can request connection to the network with the `Connect()` method, just passing the APN, user and password strings. If no user or password are needed, they should be given as empty strings.

The `Connect()` method will return only after all the connection steps have been performed, including the network interface and routing setup.

The `Disconnect()` method allows the user to request the disconnection from the network. In the same way, the method will only return once all the disconnection steps have been performed.

The `Disconnecting` and `Connecting` states returned by the `GetConnectionStatus()` method are only applicable when the method is run from another thread or process than the one which requested the actual connection or disconnection.

The `GetDataPort()` method will return the name of the network interface being managed by `rmfd`, useful for the case where multiple network interfaces are exposed by a single modem and only one is used.

4.3.10. Network connection statistics API

```
bool GetConnectionStats (uint32_t &txPacketsOk,
                          uint32_t &rxPacketsOk,
                          uint32_t &txPacketsError,
                          uint32_t &rxPacketsError,
                          uint32_t &txPacketsOverflow,
                          uint32_t &rxPacketsOverflow,
                          uint64_t &txBytesOk,
                          uint64_t &rxBytesOk);
```

The `RaveModemFactory` allows to query which are the number of received and transmitted packets and bytes in the ongoing connection, if any.

4.4. Example

```
/*
 * Small librmf client example
 *
 * Assuming RMF was installed in /usr, compile with:
 * $> g++ -o example -I /usr/include/librmf -lrmf example.cpp
 */

#include <iostream>
#include <rmf-operations.h>

int
main (int argc, char **argv)
{
    std::string manufacturer;

    try {
        manufacturer = Modem::GetManufacturer ();
    } catch (std::exception const& e) {
        std::cout << "Exception: " << e.what() << std::endl;
        return -1;
    }

    std::cout << "Manufacturer: " << manufacturer << std::endl;
    return 0;
}
```


5. rmfcli

The command line interface provided in the RaveModemFactory system allows to test every action that the librmf library exposes.

Note: rmfcli is just a test tool.

The suggested way to use RMF is to write a custom connection manager that uses librmf directly.

The tool can be run even if there is another user application using the librmf interfaces.

The following lines show the output of running `rmfcli --help`:

```
Usage: rmfcli <option>

Options:
  -y, --target-address="ip"
  -Y, --target-port="port"

Actions:
  -f, --get-manufacturer
  -d, --get-model
  -j, --get-software-revision
  -k, --get-hardware-revision
  -e, --get-imei
  -i, --get-imsi
  -o, --get-iccid
  -z, --get-sim-info
  -L, --is-locked
  -U, --unlock="pin"
  -E, --enable-pin="pin"
  -G, --disable-pin="pin"
  -F, --change-pin="pin newpin"
  -p, --get-power-status
  -P, --set-power-status="[Full|Low]"
  -Z, --power-cycle
  -a, --get-power-info
  -s, --get-signal-info
  -r, --get-registration-status
  -t, --get-registration-timeout
  -T, --set-registration-timeout="timeout"
  -c, --get-connection-status
  -x, --get-connection-stats
  -C, --connect="apn user password"
  -D, --disconnect
  -A, --is-available

Common actions:
  -h, --help
  -v, --version
```