TRX SDK

Version: 2025-06-13

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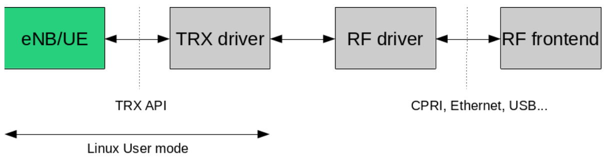
1 Introduction

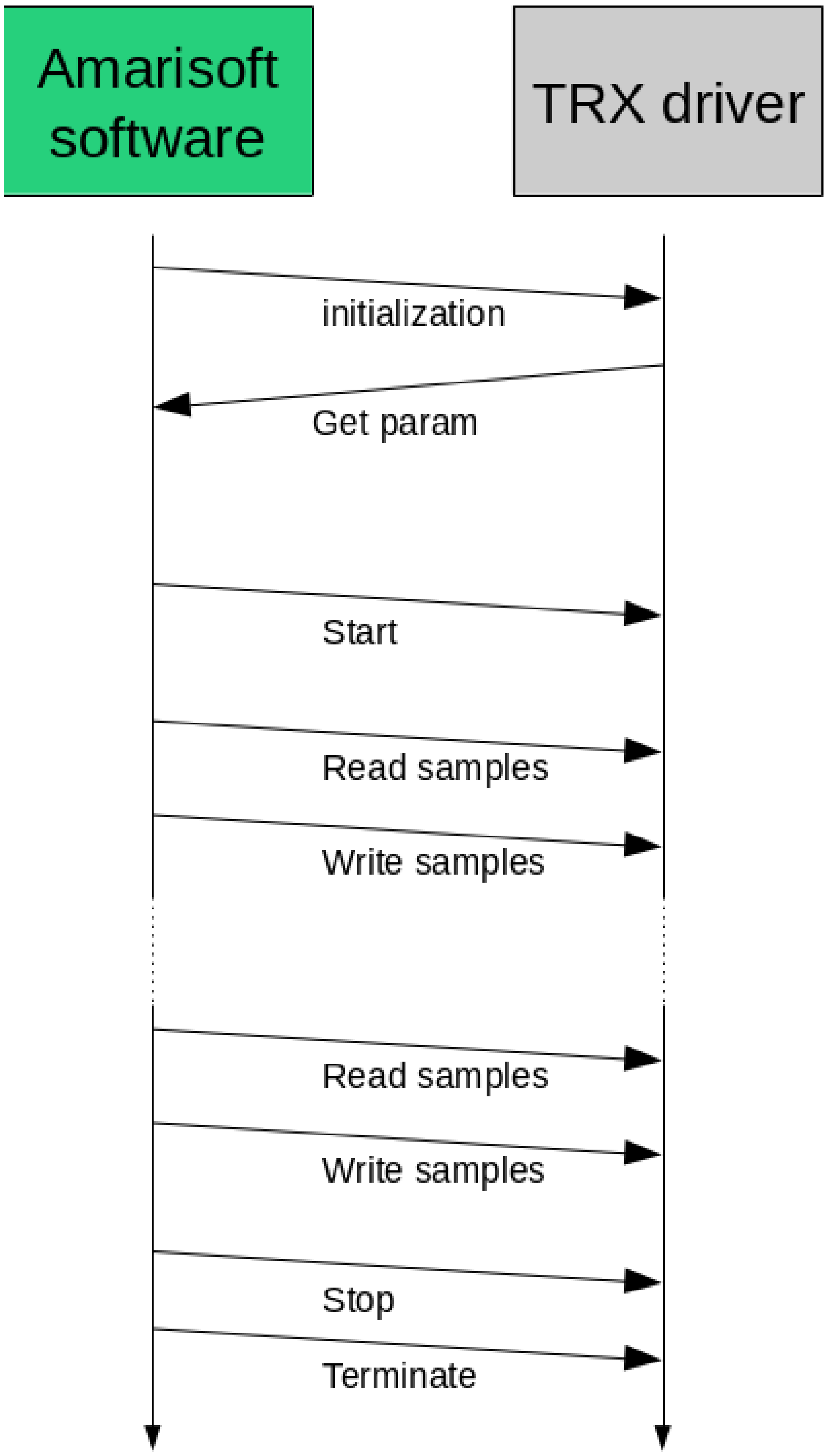
The purpose of this document is to explain how to implement a driver for Amarisoft software(s) to use any kind of frquency domain radio frontend.
Such a driver must implement the TRX API defined in `trx_driver.h` and will be used by Amarisoft software as a shared library.
This API a pure standard C API but may be implemented in any language as long as it respects ABI.

The shared library will be loaded by Amarisoft software that will control its lifetime.
This implies to run in user mode.



In this document, `software` will represent Amarisoft Software (Ex: eNB, UE...) and `driver` will represent the shared library implementing the TRX API.

2 Lifetime


Amarisoft software
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2.1 Initialization

Software will first manually open the driver, will load the only required exported symbol (`trx_driver_init`) and will call it.

In this phase the driver will provide the various callbacks that the software will use during runtime.
The function `trx_get_param_string` and `trx_get_param_double` may be used to access fields of `rf_driver` section of software configuration file.
Any context may be saved inside `TRXState->opaque`.

After initialization, software may call any of the provided callbacks.

We recommend to also read the commentary associated to each callback in `trx_driver`.

The minimum set of callbacks to be implemented are:

- trx_start_func2
- trx_read_func2
- trx_write_func2
- trx_end_func

2.2 Sample rate

After initialization has been done, the sofware will require estimating the signal sampling rate for each RF port.
The sample rate can be either manually set in software config file (eNB (`https://tech-academy.amarisoft.com/lteenb.doc#prop.rf_ports.sample_rate`), UE (`https://tech-academy.amarisoft.com/lteue.doc#prop.sample_rate`)) or provided by the driver itself through the `trx_get_sample_rate_func` callback.

2.3 Start

Once initialization is done, software will call `trx_start_func2` function to provide to the driver the configuration of all RF ports.
A RF port defines a signal at a specific frequency and bandwidth with multiple antenna.

2.4 Runtime

2.4.1 Clock

Software don't use any local clock such as the OS clock or any other mechanism.
Its progress is full driven by the reception of IQ samples provided by the driver.
In other words, any computed time inside software will be derived by the amount of received samples.
This time information is called a timestamp, expressed in samples and can be easily converted to natural unit (s, ms...) using the sample rate.

```
<time> = <timestamp> / <sample_rate>
```

2.4.2 IQ reception

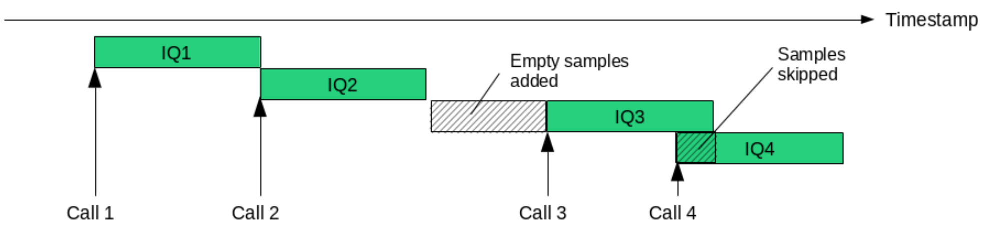
Regularily, the software will call `trx_read_func2`.
The purpose of this function is to wait for available IQ samples and provide them to the software with a timestamp.

The timestamp represent the time at which the signal corresponding to the IQ samples has been received at antenna level.
Its origin can be arbitrary except in case where eNB has to be synchronized with other base stations, the origin must be Jan 1st 1970 (TAI).

The provided timestamp is the timestamp of the first provided IQ sample.

As the software uses the provided timestamp for its clock, any subsequent call to this callback should provide IQ samples with a greater timestamp.
If not the IQ samples wil be skipped.
If any discontinuity is found, the missing IQ samples will be generated with an empty signal.

If no new IQ samples are available since the last call, the function should block until new IQ samples are available.



2.4.3 IQ transmition

Regularily, the software will call `trx_write_func2`.
The purpose of this function is to provide IQ samples to be transmitted to the radio fronted.
The associated timestamp defines when the signal has to be sent and is based on the same timestamp clock used for reception.
Basically it means that the timestamp should be in the future to let the RF chain some time to send it.
If it is not the case, it means the software is late and samples should be skipped.
How much in advance the IQ samples are provided depends on many parameters with a optenital high jitter, which means in practical driver should be able to buffer the IQ sample somewhere.

The call should not block and should be as fast as possible.

Note that to identify RX/TX period for TDD case, the callback will be called with `samples` being NULL (The flag `TRX_WRITE_FLAG_PADDING` will be also set) during RX period.
This information may be used to turn on/off any PA or switch.

2.4.4 Stop

2.4.5 Terminate

3 IQ samples

Amarisoft IQ are coded with 32 bits float type and have following range:

```
-1.0 <= IQ <= 1.0
```

It is up to the driver to normalize IQ and to adapt their level for any AGC or predefined gain.
The type of samples in read and write callbacks are void* but should be casted to `TRXComplex` format.

It is up to the driver to convert IQ samples from/to this format. Note that this step is crucial for performances and you should have it optimized as much as possible (See [Optimizations], page 7).

4 Example

A dummy driver example is implemented in `trx_example.c`.

`trx_example` is a dummy transceiver driver for the Amarisoft LTE eNodeB. It simulates zero samples coming from a source synchronized to the PC clock and optionally outputs the maximum amplitude of the downlink I/Q samples.

You can compile the trx_example driver by just typing `make`.
Then copy `trx_example.so` to the lteenb installation directory.
You can enable it with the following property in the eNodeB configuration:

```
rf_driver: {
   name: "example",
   dump_max: 1, /* enable maximum amplitude output */
},
tx_gain: 0,
rx_gain: 0,
sample_rate: 11.52, /* set the sample rate to 11.52 MHz */
```

5 Optimizations

5.1 IQ samples convertion

For fast IQ samples convertion, optimized routine are available in `convert16_see.c`.

This is a example code of fixed point/floating point numbers optimized with SSE instructions. This file must be compiled with "-msse4.1" gcc option.

For more information on Intel SSE/AVX: `https://software.intel.com/sites/landingpage/IntrinsicsGuide/`

5.2 Multi-threading

To take advantage of multiple cores CPU architcture, the read and write callbacks have a multi-thread flavour. Each direction may be implemented independently.

5.2.1 TX

If `trx_write_mt_func` is implemented, the software may call it simultaneously from different thread so that you need to ensure to avoid any thread race condition.
Functionnaly speaking, this function must do the same as `trx_write_func2`.

5.2.2 RX

To allow multi-threaded IQ reception, the driver needs to implement the two following callbacks:

`trx_read_timestamp_func`
: Will be called sequentially from the same thread as for `trx_read_func2` but does not return any IQ sample, only incremented timestamp will be used.
This means that this function must tell the software up to what timestamp IQ samples are available.
If this callback is not implemented, the software will use the standard `trx_write_func2`.

`trx_read_mt_func`
: This callback is used to retrieve IQ samples at a defined timestamp and be called simultaneously from multiple threads.
It `trx_read_mt_func` will be called with `timestamp + count` always below the last timestamp provided by `trx_read_timestamp_func`.
Any IQ samples will never be requested twice or simultaneousl which means that as soon as they have been provided, they can be discarded.
Part of IQ samples may not be requested (Ex: during TDD TX time or if they are not necessary).
If thoses callbacks are not implemented, the software will use the standard `trx_read_func2`.

5.3 NUMA

If your system has a NUMA architecture (Multiple socket, NUMA CPU cores) and your driver is using memory and/or hardware bounded to a NUMA node, the software can take advantage of it by allocating its memory and processing IQ samples on the same NUMA node.
For instance, if your driver is communicating with a PCIe device, allocating memory and processing IQ samples on the same NUMA node the PCIe lanes are connected to will reduce the system memory bandwidth and may drastically improve performances.

To take advantage of it, you need to implement the `trx_get_numa_nodes` callback that will be called before `trx_start_func2`.

6 Troubleshooting

6.1 Logs

To ease troubleshooting, you can access the software log system with `trx_log_func` function provided in `TRXState` during init.
Some helpers are also provided: `trx_log_full`, `trx_log`, `trx_log1`.

The log function is thread safe but if you want to use them from a thread created by the driver, the thread has to be a POSIX thread and `trx_pthread_init`/`trx_pthread_terminate` must be called at thread creation/termination.

A log may be skipped depending on its level and the current software TRX layer level configuration. To avoid overhead of log creation in the case where a log would be skipped, the driver may implement `trx_log_set_level_func` to be informed of the current configuration (and subsequent runtime changes) and test level threshold earlier.

6.2 Metadata

Software can get some feedback from the driver to log potential errors/problems on IQ samples handling.

`TRXReadMetadata`
: This structure is passed to `trx_read_func2` and `trx_read_mt_func` callbacks. The driver may set the overflow property if TRX_READ_MD_OVERFLOW is set and drivers estimate it has an overflow in its reception buffer (i.e IQ samples are lost.

`TRXWriteMetadata`
: This structure is passed to `trx_write_func2` and `trx_write_mt_func` callbacks. If TRX_WRITE_MD_UNDERFLOW is set, the driver may set cur_timestamp_set to 1 and fill cur_timestamp with the estimated current timestamp at antenna level.
This will inform software if the provided IQ samples are lost (Because `timestamp > cur_timestamp`) or not and will also provide information on the remaining time budget.
With this, the software can take decisions to reduce its processing to go faster and will be used to display stats in the `t cpu` monitor command (RX/TX diff).
If this is not set, the software will rely on the last timestamp provided by read APIs that may be less accurate.

7 Remote API

Since version 14 of API you can receive and send messages via remote API.
Please refer to the remote API section of your software component for usage.

`trx_msg_recv_func` can be called from a different thread than read and write functions. `TRXMsg` API is thread safe.

7.1 Receive messages

All `trx` messages will be sent to `trx_msg_recv_func`.
Use `TRXMsg->get_double` and `TRXMsg->get_string` API to get data from incoming message.
Use `TRXMsg->set_double` and `TRXMsg->set_string` API to set data for response.

Then use `TRXMsg->send` API when your response is ready to be sent.

If you need to send response later, use `TRXMsg->set_timeout` API, then call `TRXMsg->send` API when your response is ready to be sent.

The `timeout_cb` will be called when timeout occurs. You need to call `TRXMsg->send` to free resources.

Those APIs are thread safe but if you want to use them from a thread created by the driver, the thread has to be a POSIX thread and `trx_pthread_init`/`trx_pthread_terminate` must be called at thread creation/termination.

7.2 Send messages

To send a message, call `trx_msg_send_func`.
This will create a message that you can populate with `TRXMsg->set_double` and `TRXMsg->set_string` API.

Then call `TRXMsg->send` API to send your message.

The message type will be `trx` and the client must register to this type of message to receive it.

8 Change history

8.1 Version 2024-09-13

- added `rx_timestamp_offset` to cell info
- added `pattern2` to cell info

8.2 Version 2024-06-14

- added trx_write_mt_end_func API for multi-threading
- added NR TDD pattern 2 in cell info

8.3 Version 2023-12-15

- Major update for all concepts

9 License