Using libRaptorQ library: RFC6330 interface

August 4, 2018

Abstract

libRaptorQ is a C++11 implementation of the RaptorQ Forward Error Correction. It includes two interfaces, one derived from the RFC6330 standard, and one RAW API for a more flexible and easy usage.

This document is only about the RFC6330 interface.

The implementation was started as a university laboratory project, and will be later used and included in Fenrir, the maintainer's master thesis project.

Contents

1 Contacts

The main development and dicussions on the project, along with bug reporting, happens on the main website.

Mailing Lists — Mailing lists are available at https://fenrirproject.org/lists
The two mailing lists are for development and announcements, but due to the low traffic of the development mailing list, it can also be used by users for questions on the project.

IRC — Since there are not many developers for now, the main irc channel is #**fenrirproject** on freenode

2 Build & install

2.1 Get the source code

This document follows the 1.0 stable release.

You can get the tarballs from the main website here:
https://fenrirproject.org/Luker/libRaptorQ/tags

Or you can check out the repository (warning: development in progress):

```
$ git clone --recurse-submodules \
        https://fenrirproject.org/Luker/libRaptorQ.git
```

You can also get it from github:

```
$ git clone --recurse-submodules \
        https://github.com/LucaFulchir/libRaptorQ.git
```

GPG verification: Once you have cloned it, it's always a good thing to check the repository gpg signatures, so you can import my key with:

```
$ gpg --keyserver pgp.mit.edu --recv-key \
                    7393DAD255BEB5751DBDA04AB11CD823BA278C85
```

Now you have the source, and the key, it's enough to check the signature of the last commit:

```
$ git log -n 1 --show-signature
```

The important part is that you get something like this:

```
gpg: Signature made Mon 11 Dec 2017 21:55:28 CET
gpg:                using RSA key 8F7474044095B405D0F042F0A2CCA134BC7C8572
gpg: Good signature from "Luca Fulchir <luker@fenrirproject.org>" [unknown]
gpg:                 aka "Luca Fulchir <luca@fulchir.it>" [unknown]
gpg: WARNING: This key is not certified with a trusted signature!
gpg:          There is no indication that the signature belongs to the owner.
Primary key fingerprint: 7393 DAD2 55BE B575 1DBD A04A B11C D823 BA27 8C85
```

And as long as you got the right key, and you find the **"gpg: Good signature"** string, you can be sure you have the right code.

The main development happens in the *master* branch, while we keep one branch for each stable version.

2.2 Dependencies

libRaptorQ has 4 dependencies:

Eigen3 : This is used for matrix manipulation, which is a big part of RaptorQ.

lz4 : Used to compress cached precomputations.

git : This is used not only to get the source, but also by the build system. We get the last git commit id and feed it to clang or gcc as seed for their internal random number generator. This makes it possible to have reproducible builds.

optionparser : Library used to parse the command line easily in C++, without exceptions

All dependencies are included in the sources, so you do not need to download and compile them.
Eigen3 is only needed at build time, so there is no need to download it again. we use the 3.3.4 version.
LZ4 is included as a git submodule. if you do not have it, run:

```
$ git submodule init
$ git submodule update
```

and LZ4 will be built statically in the library (it will not be installed on the system)

2.3 Build & Install

libRaptorQ uses the cMake build system, so things are fairly standard:

```
$ cd libRaptorQ.git
$ mkdir build
$ cd build
$ cmake ../
$ make -j 4
```

By default, the libRaptorQ project tries to have deterministic builds. This means that if you compile things twice, or with two different computers, the hash of the resulting library will be the same, provided that the same compiler (clang, gcc 4.8, gcc 4.9 etc) was used. Currently the only exception is the clang compiler with the *PROFILING* option enabled, and this will not likely be solved.

There are lots of options, you can use in cmake. As always, you can change them by adding "**-Dcmake_option=cmake_value**" when calling cmake.

You can always use the cmake-gui or ccmake commands to have the list of possible options.

The ones we recognize are:

LTO : ON/OFF. Default:**ON**. Enables *Link Time Optimizatios* for clang or gcc. Makes libraries smaller and better optimized.

PROFILING : ON/OFF. Default:**ON**. Profiling compiles everything once, then runs a test to see which code paths are used more, and then recompiles everything again, but making sure that the binary is optimized for those paths. Works with clang and gcc. Provides a slight speedup.

CMAKE_C_COMPILER : gcc and clang are directly supported. other should work, too. This is only used if you want to build the C example.

CMAKE_CXX_COMPILER : g++, clang++ are directly supported. other should work, too.

CLANG_STDLIB : ON/OFF. Default:**OFF**.use clang's libc++ standard library. Only available with clang.

CMAKE_BUILD_TYPE : Type of build. you can choose between "Debug", "Release", "MinSizeRel" or "RelWithDebInfo"

CMAKE_INSTALL_PREFIX : Default to */usr/local*. Change it to fit your distribution guidelines.

RQ_ENDIANNESS : `Auto,BigEndian,LittleEndian` Force the build to use one endianness ot the other

RQ_LINKER : `Auto,gold,ld,bsd` Force the build to use one linker or the other

USE_LZ4 : ON/OFF. Default:**ON**. compile with support for lz4

Then you can build everything by running:

```
$ make -j 4
```

Of course, you can configure the number of parallel jobs (the *-j* parameter) to be what you need.

Optional make targets: The following optional targets are also supported:

```
$ make docs tests examples
$ make everything
```

The "docs" target builds this document, but you need latex with the refman style. The tests are only useful to check perfromance of rfc compliance right now. "examples" compiles the C and C++ examples, which will not be installed.

Install: The installation process is very simple:

```
$ make install DESTDIR=...
```

You can change the *DESTDIR* parameter to fit your distribution guidelines.

3 Working with RaptorQ

3.1 Theory (you really need this)

To be able to work with liRaptorQ, you must first understand how the RaptorQ algorithms works. We won't go into the details, but just what you need to be able to tune the algorithm to your needs.

Fountain codes: Fountain codes are a special *Forward-Error-Correcting* code class, which characteristic is simple: if you want to send K packets, you actually send $K+X$ packets, and the receiver only needs to get any K packets to be able to reconstruct your data. The number X of overhead packets can be as big as you need (theoretically infinite), so you can tune it to be slightly higher than the expected packet loss.

Systematic codes: RaptorQ is also a systematic code. This means that those first K packets are the input *as-is* (**source symbols**), and the X packets (**repair symbols**) have the information needed to recover any of the lost source packets. This has the big advantage of avoiding any kind of time and memory consuming decoding if there is no packet loss during the transmission.

Complexity: The RaptorQ algorithm is often presented as having a linear time encoder and decoder. This is both false and misleading. Generating the source or repair symbols from the intermediate symbols has linear complexity. Generating the intermediate symbols has cubic complexity on the number of symbols. Which is a completely different thing. It is still very quick. On a core i7, 2.4Ghz, you need to wait *0.4ms* for 10 symbols, *280ms* for 1.000 symbols, but it can take an hour for 27.000 symbols. RaptorQ handles up to 56.403 symbols.

Caching libRaptorQ can work with big matrices that take a lot of time to compute. For this reason the matrices can be saved once they have been computed the first time. libRaptorQ uses a **local** cache. The matrix can be compressed with LZ4.

3.2 RFC6330: Blocks & Symbols

To understand how to properly use and tune libRaptorQ, you first need to understand how RaptorQ and the **RFC6330** handles its inputs, outputs, and what the time and memory constraints are.

Input sequencing: The RC6330 needs to have the whole input you want to send before it can start working.
This means that it might be a little more difficult to use in live-streaming contexts, or where you need real-time data, but for that you probably want to use the single-block API in the **RaptorQ** C++ namespace. There is a second document tracking that interface, this document tracks only the RFC6330 interface.

Once you have the whole input, RFC6330 divides it into **blocks**. Each block *is encoded and decoded independently* and will be divided into **symbols**. Each symbol *should* be transmitted separately in its own packet (if you are on the network).

Sizes: Each input can have up to *256 blocks*, each block can have up to 56.403 *symbols*, and each symbol can have up to $2^{16} - 1$ *bytes*long. This gives a maximum files size of almost 881 GB (946270874880 bytes to be exact)

Interleaving: An other feature of RFC6330 is to automatically provide some interleaving of the input data before transmitting it. This means that one symbol will not represent one sequential chunk of your input data, but more likely it's the concatenation of different **subsymbols**. The size of the subsymbol must thus be a fraction of the symbol size. *This feature is not used if you set the size of the subsymbol to the size of symbol.*

Memory and Time: Memory and time requirements are to be considered, though, as RFC6330 needs to run a cubic algorithm on matrix of size $K * K$, where K is the number of symbols in each block.
The algorithm needs to keep in memory two of these matrices, although most of the work is done on only one.
This is actually a lot. More benchmarks and optimizations will come later, for now remember that with 10 symbols it takes something like 0.4ms on a core i7 2.4GHZ, 280ms with 1000 symbols, and up to an hour with 27.000 symbols.

3.3 C++ interface

To use the C++ interface you only need to include the **RaptorQ/RFC6330_v1.hpp** header, and link **libRaptorQ** and your threading library (usually *libpthread*).

You can also use the library as a header-only include, by including **RaptorQ/RFC6330_v1_hdr.hpp**. All your code should keep working even if you switch between linked and header-only at a later date. If you use the header-only version, remember to have Eigen3 in your include path and to include the needed definitions, `RQ_LITTLE_ENDIAN` or `RQ_BIG_ENDIAN`

Namespace Since the libRaptorQ library now has two very different usages, everything was split into two namespaces: **RFC6330** and **RaptorQ**. The names should be explanatory: the first namespace (that we cover in this document) is for the RFC interface, while the second namespace is for the low-level interface.

Since we will cover only the **RFC6330** namespace here, remember that everything we talk about is in this namespace.

Both the RFC6330 and the RaptorQ namespace are versioned so you can keep using old APIs while we change stuff. just add `__v1`

to select the first version of the API. E.g: `RFC6330__v1`

Templates There are two main classes you will use:

```
template <typename Rnd_It, typename Fwd_It>
class Encoder

template <typename In_It, typename Fwd_It>
class Decoder
```

As you might guess, the classes for the encoder and decoder take two template parameters.
For the **Encoder**, the first parameter *MUST* be a *random access iterator* to the input data, and the second parameter is an *forward iterator*. The random access iterator will be used to scan your input data, and perform an interleaving (if you did not set the same size the symbol and to the subsymbol). The forward iterator will be used to write the data to your structure.
The same is done for the **Decoder**, but we do not need to do any interleaving on the input, so the first iterator can be just an input iterator, and nothing more.

3.3.1 Caching precomputations

libRaptorQ can now cache the most used matrices for a quicker reference. The cache can be scaled up or down dynamically.

local_cache_size : **const uint64_t local_cache**
return: bool
Set the local cache size. returns false on error.

get_local_cache_size() : **return: uint64_t**
get the size of our local cache

supported_compressions() : **return: Compress**
Get the bitmask of all supported compression algorithms. currently only **Compress::NONE** and **Compress::LZ4**.

get_compression() : **return: Compress**
Get the current compression used.

set_compression : **const Compress compression**
return: bool
Try to set a compression algorithm. LZ4 is not a mandatory dependency, so we might not have it

3.3.2 Thread pool

Both the encoder and the decoder can work with multiple blocks at the same time, so it makes sense to have a thread pool for such work.

set_thread_pool : **Input: const size_t threads**
. **const uint16_t max_block_concurrency**
. **const RaptorQ__v1::Work_State exit_type**
return: bool
set a pool of a certain number of threads. But the decoder is special: if one decoding fails we can always try again once we have at least one other symbol. The second parameter tells the pool how many times we can try to decode the same block concurrently. 1 is a safe option.
The final argument is used when downsizing the queue: what do we do if all the threads are running but you asked to have less threads?

```
enum class Work_State : uint8_t {
    KEEP_WORKING
    ABORT_COMPUTATION
};
```

3.3.3 The Encoder

The constructor is the following:

```
Encoder (const Rnd_It data_from, const Rnd_It data_to,
                    const uint16_t min_subsymbol_size,
                    const uint16_t symbol_size,
                    const size_t max_sub_block);
```

As we said, the RFC will decide by itself how many blocks each input will have, the actual size of the subsymbol, and the size of the blocks. Although needed for RFC compliance, you probably do not care about the *min_subsymbol_size*, in which case the safe choice is to put it at the same size of the symbol.
The *max_sub_block* the the maximum size of a sub-block in bytes. Again, unless you *really* understand the RFC, you should probably ignore this and put it to a high value. This parameter is used to limit the block size used by the RFC, and is the size (in bytes) of the biggest block you allow the RFC to use.
safe settings for max_sub_block: sub_symbol_size * block_size.

You can instantiate an encoder for example by doing:

```
std::vector<uint32_t> input, output;
...
using T_it = typename std::vector<uint32_t>::iterator;
RFC6330::Encoder<T_it, T_it> enc (input.begin(),
                                  input.end(),
                                  4, 1444, 10000)
```

This will create an Encoder that works on vectors of unsigned 32 bit integers for both input and output, that will create symbols of size 1444 bytes, interleaving your input every 4 bytes, and try to work with a big number of symbols per blocks.

The available methods for the encoder are the following:

operator bool() : **return:bool**
False if constructor parameters did not make sense. Else true.

OTI_Common() : **return: OTI_Common_Data**, aka *uint64_t*.
Keeps total **file size and symbol size**. You need to send this to the receiver, so that it will be able to properly decode the data.

OTI_Scheme_Specific_Data() : **return: OTI_Scheme_Specific_Data**, aka *uint32_t*.
Keeps number of **source blocks, sub blocks, and alignment**. As for the OTI_Common_Data, you need to send this to the receiver to be able to properly decode the data.

compute : **Input: const Compute flags**
return: std::future<std::pair<Error, uint8_t> >

For C++11 only (automatically disabled on C++98). Start the computation, return a future, which has a pair of Error and the number of blocks ready.
Compute flags:

```
enum class Compute : uint8_t {
    NONE
    // report every time there is more data, but
    only
    // if that data starts at the beginning.
    PARTIAL_FROM_BEGINNING
    PARTIAL_ANY
    COMPLETE // only when all the data is available
    NO_BACKGROUND // only return after the
    computation is finished
    NO_POOL // do not use the thread pool
    NO_RETRY // do not retry if we failed, even if
    there is more data
};
```

precompute_max_memory : **return: size_t**
Each precomputation can take a lot of memory, depending on the configuration, so you might want to limit the number of precomputations run in parallel depending on the memory used. This method returns the amount of memory taken by **ONE** precomputation.

encode : **Input: Fwd_It &output, const Fwd_It end, const uint32_t esi, const uint8_t sbn.**
return:size_t.
Take as input the iterators to the data structure into where we have to save the encoded data, the **Encoding Symbol Id** and the **Source Block Number**. As you are writing in C++, you probably want to use the iterators begin/end, though. Returns the number of written iterators (**NOT** the bytes)

encode : **Input: Fwd_It &output, const Fwd_It end, const uint32_t id.**
return:size_t.
Exactly as before, but the **id** contains both the *source block number* and the *encoding symbol id*

begin() : **return: Block_Iterator<Rnd_It, Fwd_It>**
This returns an iterator to the blocks in which the RFC divided the input data. See later to understand how to use it.

end() : **return: const Block_Iterator<Rnd_It, Fwd_It>**
This returns an iterator to the end of the blocks in which the RFC divided the input data. See later to understand how to use it.

free : **Input: const uint8_t sbn**
return: void
Each block takes some memory, (a bit more than $symbols * symbol\_size$), so once you are done sending source and repair symbols for one block, you might want to free the memory of that block.

blocks() : **return: uint8_t** The number of blocks.

block_size() : **Input: const uint8_t sbn**
return: uint32_t
The block size, in bytes. Each block can have different symbols and thus different size. The last block also might have more padding, and with this you get the real size of that block, without the padding.

symbol_size() : **return: uint16_t** The size of a symbol.

symbols : **Input:uint8_t sbn**
return: uint16_t
The number of symbols in a specific block. different blocks can have different symbols.

extended_symbols : **Input:uint8_t sbn**
return: uint16_t
The **real, internal** number of symbols in a specific block. This can be slightly higher than the `symbols()` call, and *you probably do not need this* for anything except if you are trying to know more about the RaptorQ algorithm

max_repair : **Input: const uint8_t sbn)**
return: uint32_t
The maximum amount of repair symbols that you can generate. Something less than 2^{24}, but the exact number depends on the number of symbols in a block

3.3.4 Blocks

With the *begin()/end()* calls you get *Input iterators* to the blocks. A Block has the following type:

```
template <typename Rnd_It, typename Fwd_It>
class Block
```

and exposes the following methods:

begin_source() : **return: Symbol_Iterator**

end_source() : **return: Symbol_Iterator**

begin_repair() : **return: Symbol_Iterator**

end_repair() : **Input: const uint32_t max_repair**
return: Symbol_Iterator

id() : **return: uint8_t**

max_repair() : **return: uint32_t**

symbols() : **return: uint16_t**

extended_symbols() : **return: uint16_t**
As before, this is the amount of internal symbols, that include padding symbols. You probably do not need this unless you are trying to know more about the RaptorQ algorithm

block_size() : **return: uint32_t**

As the names explain, you will get an iterator to the symbols in the block. As the number of repair symbols can vary, for now you get two separate begin/ends, so that you can check when you sent the source symbols, and how many repair symbols you send.
The other functions are helpers for the details of the block.

3.3.5 Symbols

Finally, through the *Symbol_Iterator Input Iterator* we get the **Symbol** class:

```
template <typename Rnd_It, typename Fwd_It>
class Symbol
```

which exposes the following methods we need to get the symbol data:

operator() : **Input:Fwd_It &start, const Fwd_It end**
return: uint64_t
takes a forward iterator, and fill it with the symbol data. returns the number of written iterators.

id() : **return: uint32_t**
return the id ($sbn + esi$) of this symbol, that you need to include in every packet you send, before the symbols.

block() : **return: uint8_t**
return the *block* of this symbol.

esi() : **return: uint32_t**
return the *esi* of this symbol.

3.3.6 The Decoder

The decoder is a bit simpler than the encoder.

There are two constructors for the Decoder:

```
std::vector<uint32_t> input, output;
using T_it = typename std::vector<uint32_t>::iterator;
RaptorQ::Decoder<T_it, T_it> dec (
                const OTI_Common_Data common,
                const OTI_Scheme_Specific_Data scheme)

RaptorQ::Decoder<T_it, T_it> dec (uint64_t size,
                                  uint16_t symbol_size,
                                  uint16_t sub_blocks,
                                  uint8_t blocks)
```

Which should be pretty self-explanatory, once you understand how the encoder works: you can either get the `OTI` parameters from the Encoder or you can provide the raw values by yourself (only if you know what you are doing)

The remaining methods are:

begin() : **return: Block_Iterator<In_It, Fwd_It>**
This returns an iterator to the blocks in which the RFC divided the input data.

end() : **return: const Block_Iterator<In_It, Fwd_It>**
This returns an iterator to the end of the blocks in which the RFC divided the input data.

operator bool() : **return: bool**
check if the Decoder was initialized properly

compute : **Input: const Compute flags**
return: std::future<std::pair<Error, uint8_t> >
Only enabled if you use C++11. Start the computation as soon as enough data is available.
Compute flags:

```
enum class Compute : uint8_t {
NONE
// report every time there is more data, but only
// if that data starts at the beginning.
PARTIAL_FROM_BEGINNING
PARTIAL_ANY
COMPLETE // only when all the data is available
NO_BACKGROUND // only return after the computation
    is finished
NO_POOL // do not use the thread pool
NO_RETRY // do not retry if we failed, even if there
     is more data
};
```

end_of_input : **Input: const Fill_With_Zeros fill**
. **const uint8_t block**
return: std::vector<bool>
Tell the decoder that we know that there will be no more data for this block. The first parameter is an `enum`, either **Fill_With_Zeros::YES** or **Fill_With_Zeros::NO** If you choose `YES` then the repair symbols will be discarded, the missing symbols will be filled with zeros and for output you will get the bitmask for which byte was received (true) or was filled with zeros (false).
If you choose **Fill_With_Zeros::NO** you will get *an empty vector*

end_of_input : **Input: const Fill_With_Zeros fill**
return: std::vector<bool>
Same as before, but we know that there will be no more inputs for any block.

decode_symbol : **Input: Fwd_It &start**
. **const Fwd_It end**
. **const uint16_t esi**
. **const uint8_t sbn return: uint64_t**
Decode a single symbol. you need to provide the block number and symbol identifier.

decode_bytes : **Input: Fwd_It &start**
. **const Fwd_It end**
. **const uint8_t skip**
return: uint64_t
Decode everything. returns the number of bytes written. You can start writing the output `skip` bytes after the first iterator in case the parameters you have used do not align (set to 0 for everyone else).

decode_bytes : **Input: Fwd_It &start**
. **const Fwd_It end**
. **const uint8_t skip**
. **const uint8_t sbn**
return: uint64_t
Same as before, but you can specify a **Single Block Number** instead of the whole output

decode_aligned : **Input: Fwd_It &start**
. **const Fwd_It end**
. **const uint8_t skip**
return: aligned_res
Same as `decode_bytes`, but yu can use this if for some weir reason the data does not align with the type of the output

```
struct aligned_res
{
uint64_t written; // iterators written
uint8_t offset; // bytes written in the last
                // iterator if it was not full
};
```

decode_block_aligned : **Input: Fwd_It &start**
. **const Fwd_It end**
. **const uint8_t skip**
. **const uint8_t sbn**
return: aligned_res
Same as before, but now you can choose the block

add_symbol : **Input: In_It &start**
. **const In_It end**
. **const uint32_t esi**
. **const uint8_t sbn**
return: RFC6330::Error
Add one symbol, while explicitly specifying the symbol id and the block id.

add_symbol : **Input: In_It &start**
. **const In_It end**
. **const uint32_t id**
return: RFC6330::Error
Same as before, but extract the block id and the symbol id from the *id* parameter

blocks_ready() : **return: uint8_t**
return the number of the blocks that are ready for output

is_ready() : **return: bool**
Whether everything has been decoded or not.

is_block_ready : **Input:const uint8_t block**
return: bool
Test if the specified block has been decoded or not

free : **Input: const uint8_t sbn**
return: void
You might have stopped using a block, but the memory is still there. Free it.

bytes() : **return: uint64_t**
The total bytes of the output

blocks() : **return: uint8_t**
The number of blocks.

block_size() : **Input: const uint8_t sbn**
return: uint32_t
The block size, in bytes. Each block can have different symbols and thus different size.

symbol_size() : **return: uint16_t** The size of a symbol.

symbols : **Input:uint8_t sbn**
return: uint16_t
The number of symbols in a specific block. different blocks can have different symbols.

3.4 C interface

The C interface looks a lot like the C++ one.
You need to include the **RaptorQ/RFC6330.h** header, and link the *libRaptorQ* library.

Static linking If you are working with the static version of libRaptorQ remember to link the C++ standard library used when compiling the library (*libstdc++* for gcc or maybe *libc++* for clang), your threding library (usually *libpthread*), and the C math library (*libm*).

API versioning To better support future changes in the API and to help you with future changes, there are only 2 API calls in this library:

RFC6330_api : **Input: uint32_t version**
return: struct RFC6330_base_api*
This will give you a pointer to a struct containing pointers to the calls you will use. The struct will change depending on which API you request (currently only number 1 is supported). Since this pointer works for every api, you have to cast it to the struct you expect, or you will not see the pointers to the function calls. Then you can use that pointer to access of the functions, like:

```
struct RFC6330_v1 *rfc = (struct RFC6330_v1*)
                                    RFC6330_api (1);
rfc->set_compression (RQ_COMPRESS_LZ4);
```

RFC6330_free_api : **Input:struct RFC6330_base_api **api**
return: void
As the name implies, this frees the given structure.

Again, we only support API version 1 at the moment.

3.4.1 Cache settings

As for the C++11 interface, you can get and set the local memory cache.

supported_compressions : **return: RFC6330_Compress**
return the bitmask of all supported compressions. currently either `RQ_COMPRESS_NONE` or `RQ_COMPRESS_LZ4`

get_compression : **return: RFC6330_Compress**
Which compression are we currently using?

set_compression : **Input: const RFC6330_Compress compression**
return: bool
Set a compression method or another.

local_cache_size : **Input: const size_t bytes**
return: size_t
Set the maximum amount of cache usable. Default: 0

get_local_cache_size : **return: size_t**
get the amount of cache configured

3.4.2 C Constructors

The first thing you need is to allocate the encoder or the decoder.

The C interface is just a wrapper around the C++ code, so you still have to specify the same things as before. A quick glance at the constructors should give you all the information you need:

```
typedef enum { RQ_NONE, RQ_ENC_8, RQ_ENC_16,
               RQ_ENC_32, RQ_ENC_64, RQ_DEC_8,
               RQ_DEC_16, RQ_DEC_32, RQ_DEC_64}
                                        RFC6330_type;
```

Encoder : **Input:const RFC6330_type type**
. **void *data_from**
. **const uint64_t size**
. **const uint16_t min_subsymbol_size**
. **const uint16_t symbol_size**
. **const size_t max_sub_block**
return: RFC6330_ptr*
Allocate an encoder. The encoder will work with uint8_t, uint16_t, uint32_t or uint64_t depending on which `RFC6330_type` you choose. The best bet is usually to work with uint8_t

Decoder : **Input:const RFC6330_type type**
. **const RFC6330_OTI_Common_Data common**
. **const RFC6330_OTI_Scheme_Specific_Data scheme**
return: RFC6330_ptr*
The `type` parameter works the same as in the encoder. The other two are parameters you get from the encoder.

Decoder_raw : **Input: RFC6330_type type**
. **const uint64_t size**
. **const uint16_t symbol_size**
. **const uint16_t sub_blocks**
. **const uint8_t blocks**
. **const uint8_t alignment**
return: struct RFC6330_ptr*
Same as before, but here you can specify the parameters by hand.

initialized : **Input: const struct RFC6330_ptr *ptr**
return: bool
check if the encoder or decoder was initialized properly.

3.4.3 Common functions for (de/en)coding

These functions are used by both the encoder and the decoder, and will be helpful in tracking how much memory you will need to allocate, or in general in managing the encoder and decoder.

The **ptr** must be a valid encoder or decoder. The names for now are self-explanatory. Blocks can have different symbols, so the size of a block and the number of symbols in a block depend on which block we are talking about.

symbols, blocks, memory

set_thread_pool :
Input: const size_t threads
. **const uint16_t max_block_concurrency**
. **const RFC6330_Work exit_type**
return: bool
Set the size of the thread pool for concurrent work. Since the decoder can fail, but also retry again if there is more data available, you can also specify how many times libRaptorQ will try to decode the same block concurrently. 1 is a safe option.
The last parameter, `RFC6330_Work` specify what to do when you are downsizing the thread pool and some threads are still working. The possible values are `RQ_WORK_KEEP_WORKING` and `RQ_WORK_ABORT_COMPUTATION`.

blocks :
Input: const struct RFC6330_ptr *ptr
return: uint8_t
The number of blocks in this RFC6330 instance

symbols :
Input: const struct RFC6330_ptr *ptr
. **const uint8_t sbn**
return: uint16_t
The number of symbols in the specified block

extended_symbols :
Input: const struct RFC6330_ptr *ptr
. **const uint8_t sbn**
return: uint16_t
The the **real, internal** number of symbols in the specified block. You probably *do not want this* unless you are trying to understand more about the RaptorQ algorithm or you are benchmarking

symbol_size :
Input:const struct RFC6330_ptr *ptr
return: size_t
The size of each symbol

free_block :
Input: struct RFC6330_ptr **ptr
. **const uint8_t sbn**
return: void
Free the allocated space for a single block

free : **Input: struct RFC6330_ptr **ptr**
return: void
Free the specified decoder or decoder and all its blocks.

Computation

compute : **Input: const struct RFC6330_ptr *ptr**
. **const RFC6330_Compute flags**
return: RFC6330_future*
Start the computation as described in the flags. Returns a wrapper to the C++11 futures. You can wait or poll the state of the future in different ways (see right below)

```
typedef enum {
RQ_COMPUTE_NONE
// report every time there is more data, but only
// if that data starts at the beginning.
RQ_COMPUTE_PARTIAL_FROM_BEGINNING
RQ_COMPUTE_PARTIAL_ANY
RQ_COMPUTE_COMPLETE // only when all the data
                    // is available
RQ_COMPUTE_NO_BACKGROUND // only return after
                     // the computation is finished
RQ_COMPUTE_NO_POOL // do not use the thread pool
RQ_COMPUTE_NO_RETRY // do not retry if we failed,
                    // even if there is more data
} RFC6330_Compute;
```

future_state : **Input: const struct RFC6330_future *f**
return: RFC6330_Error
poll the state of the future. possible results:

```
RQ_ERR_WRONG_INPUT // null pointer?
RQ_ERR_NOT_NEEDED  // you have already run
                   // future_get() on this future
RQ_ERR_WORKING     // still working on it
RQ_ERR_NONE        // ready to run future_get()
```

future_wait_for : **Input: const struct RFC6330_future *f**
. **const uint64_t time**
. **const RFC6330_Unit_Time unit**
return: RFC6330_Error
Wait for a future to become ready for X amount of time. the unit is specified in the last parameter:

```
typedef enum {
RQ_TIME_NANOSEC,
RQ_TIME_MICROSEC,
RQ_TIME_MILLISEC,
RQ_TIME_SEC,
RQ_TIME_MIN,
RQ_TIME_HOUR
} RFC6330_Unit_Time;
```

future_wait : **Input: const struct RFC6330_future *f**
return: void
Same as before, but wait indefinitely

future_get : **Input: struct RFC6330_future *future**
return: struct RFC6330_Result
Returns the state of the future. If the future is not ready it will wait indefinitely.

```
struct RAPTORQ_API RFC6330_Result {
    RFC6330_Error error;
    uint8_t sbn;
};
```

The sbn changes meaning depending to be consistent with the flags you passed to the `compute()` call.

future_free : **Input: struct RFC6330_future **f**
return: void
Free the memory allocated for the future.

3.4.4 Encoding

Now we will look at the calls specific to the encoder (that is: calls that need an encoder as the first parameter, and don't make sense in a decoder)

OTI Data

First, we need to tell the receiver all the parameters that the encoder is using, and for that two functions are provided:

```
typedef uint64_t RaptorQ_OTI_Common_Data;
typedef uint32_t RaptorQ_OTI_Scheme_Specific_Data;
```

OTI_Common : **Input: struct RaptorQ_ptr *enc**
return: RFC6330_OTI_Common_Data
Get the OTI_Common

OTI_Scheme_Specific : **Input: struct RaptorQ_ptr *enc**
return: RFC6330_OTI_Scheme_Specific_Data
Get the OTI_Scheme_Specific

Encoding

max_repair : **Input: const struct RFC6330_ptr *enc**
. **const uint8_t sbn**
return: uint32_t
return the max number of repair packets that block can have. This is around 2^{24}, so you probably always want to be much, much lower than this. The total number of symbols (source+repair) is limited in the RFC, and since the bigger blocks have more source symbols, the max number of repair symbols has to be lower in bigger blocks. Again, this is always in the ballpark of 2^{24}, you probably don't want to use this many repair symbols.

precompute_max_memory : **Input: const struct RFC6330_ptr *enc**
return: size_t
Get an estimate of how much memory (bytes) will cost the encoding of a single block. Not 100% accurate, but close enough.

encode_id : **Input: const struct RFC6330_ptr *enc**
. **void **data**
. **const size_t size**
. **const uint32_t id**
return: size_t
Get one encoded symbol, and store it in `**data`, which holds a pointer to "`size`" elements of type uint8_t, uint16_t, uint32_t or uint64_t depending on how the encoder was initialized. See `RFC6330_type` in the encoder initialization. Returns the number of elements written.

If you request repair symbols before the computation is finished, the call will block until the data is available. This calls works for both source and repair symbols, just increase the id until you finish the source symbols

encode : **Input: const struct RFC6330_ptr *enc**
. **void **data**
. **const size_t size**
. **const uint32_t esi**
. **const uint8_t sbn**
return: size_t
Same as before, but you can specify the symbol and block explicitly.

id : **Input: const uint32_t esi**
. **const uint8_t sbn**
return: uint32_t
combine the esi and the block number to form an id.

3.4.5 Decoding

As for the encoder, there are functions which are specific for a decoder. Let's look at them

General status calls

bytes : **Input: const struct RFC6330_ptr *dec**
return: uint64_t
Return the number of bytes that this decoder should output on complete, successful decoding.

blocks_ready : **Input: const struct RFC6330_ptr *dec**
return: uint8_t
Return the number of blocks ready to be returned. Useful if you don't want to wait for the whole data.
The number of blocks reported can mean either the number of sequential blocks ready, or the number of blocks regardless of order, depending on how the `compute` function was called (see `"Computation"` on 3.4.3)

is_ready : **Input: const struct RFC6330_ptr *dec**
return: bool
Test if the whole encoder is ready and all data decoded.

is_block_ready : **Input: const struct RFC6330_ptr *dec**
. **const uint8_t block**
return: bool
Test if a single block is ready and its data decoded.

Decoding calls

end_of_input : **Input: const struct RFC6330_ptr *dec**
. **const RFC6330_Fill_With_Zeros fill**
return: struct RFC6330_Byte_Tracker
Tell the decoder that there will be no more input for any block. The second parameter is an enum, it can be either **RQ_NO_FILL** or **RQ_FILL_WITH_ZEROS**.
If you use `RQ_NO_FILL` the structure returned will be empty, and the decoder will return error if there are not enough repair symbols.
If you use `RQ_FILL_WITH_ZEROS` the decoder will immediately stop decoding and all missing symbols will be filled with zeros. The returned structure will contain a bitmask so you know if each byte comes from the network (true) or it is one of the filled ones (false)

end_of_block_input : **Input: const struct RFC6330_ptr *dec**
. **const RFC6330_Fill_With_Zeros fill**
. **const uint8_t block**
return: struct RFC6330_Byte_Tracker
Same as before, but for a single block instead of the whole data.

add_symbol_id : **Input: const struct RFC6330_ptr *dec**
. **const void **data**
. **const uint32_t size**
. **const uin32_t id**
return: RFC6330_Error
Add a symbol to the decoder. The `void **data` will be cast to the correct type as specified in the decoder construction (RQ_DEC_8, RQ_DEC_16 etc..). Afterwards data will point **after** the symbol.

add_symbol_id : **Input: const struct RFC6330_ptr *dec**
. **const void **data**
. **const uint32_t size**
. **const uin32_t esi**
. **const uin8_t sbn**
return: RFC6330_Error
Same as with `add_symbol_id`, but now you can specify the esi and the block number manually

decode_aligned : **Input: const struct RFC6330_ptr *dec**
. **const void **data**
. **const uint32_t size**
. **const uint8_t skip**
return: RFC6330_Dec_Result
Decode everything as asked by the `compute()` call (see "`Computation`" on 3.4.3).
The `void **data` will be cast to the correct type as specified in the decoder construction (`RQ_DEC_8`, `RQ_DEC_16` etc..). Afterwards data will point **after** the decoded data. You can skip "skip" bytes at the beginning of **data if the pointer is not aligned with your data.

```
struct RAPTORQ_API RFC6330_Dec_Result {
    uint64_t written;
    uint8_t offset;
};
```

The result is the number of written **elements** (size depending on `RQ_DEC_8`, `RQ_DEC_16` etc).
The `offset` parameter is the amount of bytes written in the last element if the alignment used in the encoder does not fit the alignment used in the decoder. Usually you keep those synchronized, so it should be zero (element fully written)

decode_block_aligned : **Input: const struct RFC6330_ptr *dec**
. **const void **data**
. **const uint32_t size**
. **const uint8_t skip**
. **const uint8_t block**
return: RFC6330_Dec_Result
Same as before, but now you can decode a single block.

decode_symbol : **Input: const struct RFC6330_ptr *dec**
. **const void **data**
. **const uint32_t size**
. **const uint8_t skip**
. **const uint32_t esi**
. **const uint8_t sbn**
return: uint64_t
As you can expect, decode a single symbol. The `void **data` will be cast to the correct type as specified in the decoder construction (`RQ_DEC_8`, `RQ_DEC_16` etc..). Afterwards data will point **after** the decoded data.
Returns the number of bytes written

decode_bytes : **Input: const struct RFC6330_ptr *dec**
. **const void **data**
. **const uint32_t size**
. **const uint8_t skip**
return: uint64_t
Decode everything as asked by the `compute()` call (see "`Computation`" on 3.4.3).
The `void **data` will be cast to the correct type as specified in the decoder construction (`RQ_DEC_8`, `RQ_DEC_16` etc..). Afterwards data will point **after** the decoded data. You can skip "skip" bytes at the beginning of **data if the pointer is not aligned with your data.
Returns the number of written bytes.

decode_block_bytes : **Input: const struct RFC6330_ptr *dec**
. **const void **data**
. **const uint32_t size**
. **const uint8_t skip**
. **const uint8_t block**
return: uint64_t
Same as before, but now decode a single block

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