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# **Knot DNS Resolver**

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The Knot DNS Resolver is a minimalistic caching resolver implementation. The project provides both a resolver library and a small daemon. Modular architecture of the library keeps the core tiny and efficient, and provides a state-machine like API for extensions.



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## Knot DNS Resolver daemon

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The server is in the *daemon* directory, it works out of the box without any configuration.

```
$ kresd -h # Get help
$ kresd -a ::1
```

### 1.1 Configuration

- *Configuration example*
- *Configuration syntax*
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- *Configuration reference*
  - *Environment*
  - *Network configuration*
  - *Trust anchors and DNSSEC*
  - *Modules configuration*
  - *Cache configuration*
  - *Timers and events*
  - *Asynchronous function execution*
  - *Scripting worker*

In it's simplest form it requires just a working directory in which it can set up persistent files like cache and the process

state. If you don't provide the working directory by parameter, it is going to make itself comfortable in the current working directory.

```
$ kresd /var/cache/knot-resolver
```

And you're good to go for most use cases! If you want to use modules or configure daemon behavior, read on.

There are several choices on how you can configure the daemon, a RPC interface, a CLI, and a configuration file. Fortunately all share common syntax and are transparent to each other.

### 1.1.1 Configuration example

```
-- interfaces
net = { '127.0.0.1', ':::1' }
-- load some modules
modules = { 'policy' }
-- 10MB cache
cache.size = 10*MB
```

---

**Tip:** There are more configuration examples in *etc/* directory for personal, ISP, company internal and resolver cluster use cases.

---

### 1.1.2 Configuration syntax

The configuration is kept in the `config` file in the daemon working directory, and it's going to get loaded automatically. If there isn't one, the daemon is going to start with sane defaults, listening on *localhost*. The syntax for options is like follows: `group.option = value` or `group.action(parameters)`. You can also comment using a `--` prefix.

A simple example would be to load static hints.

```
modules = {
    'hints' -- no configuration
}
```

If the module accepts configuration, you can call the `module.config({...})` or provide options table. The syntax for table is `{ key1 = value, key2 = value }`, and it represents the unpacked JSON-encoded string, that the modules use as the *input configuration*.

```
modules = {
    hints = '/etc/hosts'
}
```

**Warning:** Modules specified including their configuration may not load exactly in the same order as specified.

Modules are inherently ordered by their declaration. Some modules are built-in, so it would be normally impossible to place for example *hints* before *cache*. You can enforce specific order by precedence operators `>` and `<`.

```
modules = {
    'hints > iterate', -- Hints AFTER iterate
```

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```
'policy > hints',    -- Policy AFTER hints
'view  < cache'     -- View BEFORE cache
}
modules.list() -- Check module call order
```

This is useful if you're writing a module with a layer, that evaluates an answer before writing it into cache for example.

**Tip:** The configuration and CLI syntax is Lua language, with which you may already be familiar with. If not, you can read the [Learn Lua in 15 minutes](#) for a syntax overview. Spending just a few minutes will allow you to break from static configuration, write more efficient configuration with iteration, and leverage events and hooks. Lua is heavily used for scripting in applications ranging from embedded to game engines, but in DNS world notably in [PowerDNS Recursor](#). Knot DNS Resolver does not simply use Lua modules, but it is the heart of the daemon for everything from configuration, internal events and user interaction.

## Dynamic configuration

Knowing that the the configuration is a Lua in disguise enables you to write dynamic rules. It also helps you to avoid repetitive templating that is unavoidable with static configuration.

```
if hostname() == 'hidden' then
    net.listen(net.eth0, 5353)
else
    net = { '127.0.0.1', net.eth1.addr[1] }
end
```

Another example would show how it is possible to bind to all interfaces, using iteration.

```
for name, addr_list in pairs(net.interfaces()) do
    net.listen(addr_list)
end
```

**Tip:** Some users observed a considerable, close to 100%, performance gain in Docker containers when they bound the daemon to a single interface:ip address pair. One may expand the aforementioned example with browsing available addresses as:

```
addrpref = env.EXPECTED_ADDR_PREFIX
for k, v in pairs(addr_list["addr"]) do
    if string.sub(v,1,string.len(addrpref)) == addrpref then
        net.listen(v)
    end
end
...
```

You can also use third-party packages (available for example through [LuaRocks](#)) as on this example to download cache from parent, to avoid cold-cache start.

```
local http = require('socket.http')
local ltn12 = require('ltn12')

if cache.count() == 0 then
    -- download cache from parent
    http.request {
```

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```

        url = 'http://parent/cache.mdb',
        sink = ltn12.sink.file(io.open('cache.mdb', 'w'))
    }
    -- reopen cache with 100M limit
    cache.size = 100*MB
end

```

## Asynchronous events

Lua supports a concept called *closures*, this is extremely useful for scripting actions upon various events, say for example - prune the cache within minute after loading, publish statistics each 5 minutes and so on. Here's an example of an anonymous function with `event.recurrent()`:

```

-- every 5 minutes
event.recurrent(5 * minute, function()
    cache.prune()
end)

```

Note that each scheduled event is identified by a number valid for the duration of the event, you may cancel it at any time. You can do this with anonymous functions, if you accept the event as a parameter, but it's not very useful as you don't have any *non-global* way to keep persistent variables.

```

-- make a closure, encapsulating counter
function pruner()
    local i = 0
    -- pruning function
    return function(e)
        cache.prune()
        -- cancel event on 5th attempt
        i = i + 1
        if i == 5 then
            event.cancel(e)
        fi
    end
end

-- make recurrent event that will cancel after 5 times
event.recurrent(5 * minute, pruner())

```

Another type of actionable event is activity on a file descriptor. This allows you to embed other event loops or monitor open files and then fire a callback when an activity is detected. This allows you to build persistent services like HTTP servers or monitoring probes that cooperate well with the daemon internal operations. See `event.socket()`

File watchers are possible with `worker.coroutine()` and `cqueues`, see the `cqueues` documentation for more information.

```

local notify = require('cqueues.notify')
local watcher = notify.opendir('/etc')
watcher:add('hosts')

-- Watch changes to /etc/hosts
worker.coroutine(function ()
    for flags, name in watcher:changes() do
        for flag in notify.flags(flags) do
            print(name, notify[flag])
        end
    end
end)

```

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```

end
end
end)

```

### 1.1.3 Configuration reference

This is a reference for variables and functions available to both configuration file and CLI.

- *Environment*
- *Network configuration*
- *Trust anchors and DNSSEC*
- *Modules configuration*
- *Cache configuration*
- *Timers and events*
- *Asynchronous function execution*
- *Scripting worker*

#### Environment

##### **env** (**table**)

Return environment variable.

```
env.USER -- equivalent to $USER in shell
```

##### **hostname** ([fqdn])

**Returns** Machine hostname.

If called with a parameter, it will set kresd's internal hostname. If called without a parameter, it will return kresd's internal hostname, or the system's POSIX hostname (see `gethostname(2)`) if kresd's internal hostname is unset.

##### **moduledir** ([dir])

**Returns** Modules directory.

If called with a parameter, it will change kresd's directory for looking up the dynamic modules. If called without a parameter, it will return kresd's modules directory.

##### **verbose** (true | false)

**Returns** Toggle verbose logging.

##### **mode** ('strict' | 'normal' | 'permissive')

**Returns** Change resolver strictness checking level.

By default, resolver runs in *normal* mode. There are possibly many small adjustments hidden behind the mode settings, but the main idea is that in *permissive* mode, the resolver tries to resolve a name with as few lookups as possible, while in *strict* mode it spends much more effort resolving and checking referral path. However, if majority of the traffic is covered by DNSSEC, some of the strict checking actions are counter-productive.

Glue type	Modes when it is accepted	Example glue <sup>1</sup>
mandatory glue	strict, normal, permissive	ns1.example.org
in-bailiwick glue	normal, permissive	ns1.example2.org
any glue records	permissive	ns1.example3.net

**reorder\_RR** ([true | false])

**Parameters**

- **value** (*boolean*) – New value for the option (*optional*)

**Returns** The (new) value of the option

If set, resolver will vary the order of resource records within RR-sets every time when answered from cache. It is disabled by default.

**user** (name, [group])

**Parameters**

- **name** (*string*) – user name
- **group** (*string*) – group name (*optional*)

**Returns** boolean

Drop privileges and run as given user (and group, if provided).

---

**Tip:** Note that you should bind to required network addresses before changing user. At the same time, you should open the cache **AFTER** you change the user (so it remains accessible). A good practice is to divide configuration in two parts:

```
-- privileged
net = { '127.0.0.1', '::1' }
-- unprivileged
cache.size = 100*MB
trust_anchors.file = 'root.key'
```

Example output:

```
> user('baduser')
invalid user name
> user('knot-resolver', 'netgrp')
true
> user('root')
Operation not permitted
```

**resolve** (name, type[, class = *kres.class.IN*, options = {}, finish = nil])

**Parameters**

- **name** (*string*) – Query name (e.g. 'com.')
- **type** (*number*) – Query type (e.g. *kres.type.NS*)
- **class** (*number*) – Query class (*optional*) (e.g. *kres.class.IN*)
- **options** (*number*) – Resolution options (see query flags)

---

<sup>1</sup> The examples show glue records acceptable from servers authoritative for *org* zone when delegating to *example.org* zone. Unacceptable or missing glue records trigger resolution of names listed in NS records before following respective delegation.

- **finish** (*function*) – Callback to be executed when resolution completes (e.g. *function cb (pkt, req) end*). The callback gets a packet containing the final answer and doesn't have to return anything.

**Returns** boolean

The function can also be executed with a table of arguments instead. This is useful if you'd like to skip some arguments, for example:

```
resolve {
  name = 'example.com',
  type = kres.type.AAAA,
  init = function (req)
  end,
}
```

Example:

```
-- Send query for root DNSKEY, ignore cache
resolve('.', kres.type.DNSKEY, kres.class.IN, 'NO_CACHE')

-- Query for AAAA record
resolve('example.com', kres.type.AAAA, kres.class.IN, 0,
function (answer, req)
  -- Check answer RCODE
  local pkt = kres.pkt_t(answer)
  if pkt.rcode() == kres.rcode.NOERROR then
    -- Print matching records
    local records = pkt.section(kres.section.ANSWER)
    for i = 1, #records do
      local rr = records[i]
      if rr.type == kres.type.AAAA then
        print ('record:', kres.rr2str(rr))
      end
    end
  else
    print ('rcode: ', pkt.rcode())
  end
end)
```

## Network configuration

For when listening on localhost just doesn't cut it.

**Tip:** Use declarative interface for network.

```
net = { '127.0.0.1', net.eth0, net.eth1.addr[1] }
net.ipv4 = false
```

**net.ipv6 = true|false**

**Return** boolean (default: true)

Enable/disable using IPv6 for recursion.

**net.ipv4 = true|false**

**Return** boolean (default: true)

Enable/disable using IPv4 for recursion.

**net.listen** (addresses, [port = 53, flags = {tls = (port == 853)}])

**Returns** boolean

Listen on addresses; port and flags are optional. The addresses can be specified as a string or device, or a list of addresses (recursively). The command can be given multiple times, but note that it silently skips any addresses that have already been bound.

Examples:

```
net.listen('::1')
net.listen(net.lo, 5353)
net.listen({net.eth0, '127.0.0.1'}, 53853, {tls = true})
```

**net.close** (address, [port = 53])

**Returns** boolean

Close opened address/port pair, noop if not listening.

**net.list** ()

**Returns** Table of bound interfaces.

Example output:

```
[127.0.0.1] => {
  [port] => 53
  [tcp] => true
  [udp] => true
}
```

**net.interfaces** ()

**Returns** Table of available interfaces and their addresses.

Example output:

```
[lo0] => {
  [addr] => {
    [1] => ::1
    [2] => 127.0.0.1
  }
  [mac] => 00:00:00:00:00:00
}
[eth0] => {
  [addr] => {
    [1] => 192.168.0.1
  }
  [mac] => de:ad:be:ef:aa:bb
}
```

---

**Tip:** You can use `net.<iface>` as a shortcut for specific interface, e.g. `net.eth0`

---

**net.bufsize** ([udp\_bufsize])

Get/set maximum EDNS payload available. Default is 4096. You cannot set less than 512 (512 is DNS packet size without EDNS, 1220 is minimum size for DNSSEC) or more than 65535 octets.

Example output:

```
> net.bufsize 4096
> net.bufsize()
4096
```

#### **net.tcp\_pipeline** ([len])

Get/set per-client TCP pipeline limit, i.e. the number of outstanding queries that a single client connection can make in parallel. Default is 100.

```
> net.tcp_pipeline()
100
> net.tcp_pipeline(50)
50
```

#### **net.tls** ([cert\_path], [key\_path])

Get/set path to a server TLS certificate and private key for DNS/TLS.

Example output:

```
> net.tls("/etc/knot-resolver/server-cert.pem", "/etc/knot-resolver/server-key.pem")
↔
> net.tls()
("/etc/knot-resolver/server-cert.pem", "/etc/knot-resolver/server-key.pem")
> net.listen("::", 853)
> net.listen("::", 443, {tls = true})
```

#### **net.tls\_padding** ([padding])

Get/set EDNS(0) padding of answers to queries that arrive over TLS transport. If set to *true* (the default), it will use a sensible default padding scheme, as implemented by libknot if available at compile time. If set to a numeric value  $\geq 2$  it will pad the answers to nearest *padding* boundary, e.g. if set to *64*, the answer will have size of a multiple of 64 (64, 128, 192, ...). If set to *false* (or a number  $< 2$ ), it will disable padding entirely.

#### **net.outgoing\_v4** ([string address])

Get/set the IPv4 address used to perform queries. There is also `net.outgoing_v6` for IPv6. The default is `nil`, which lets the OS choose any address.

## Trust anchors and DNSSEC

#### **trust\_anchors.config** (keyfile, readonly)

Alias for `add_file`. It is also equivalent to CLI parameter `-k <keyfile>` and `trust_anchors.file = keyfile`.

#### **trust\_anchors.add\_file** (keyfile, readonly)

##### Parameters

- **keyfile** (*string*) – path to the file.
- **readonly** – if true, do not attempt to update the file.

The format is standard zone file, though additional information may be persisted in comments. Either DS or DNSKEY records can be used for TAs. If the file does not exist, bootstrapping of *root* TA will be attempted.

Each file can only contain records for a single domain. The TAs will be updated according to [RFC 5011](#) and persisted in the file (if allowed).

Example output:

```
> trust_anchors.add_file('root.key')
[ ta ] new state of trust anchors for a domain:
.           165488 DS           19036 8 2
↪49AAC11D7B6F6446702E54A1607371607A1A41855200FD2CE1CDDE32F24E8FB5
nil
[ ta ] key: 19036 state: Valid
```

**trust\_anchors.hold\_down\_time = 30 \* day**

**Return** int (default: 30 \* day)

Modify RFC5011 hold-down timer to given value. Example: 30 \* sec

**trust\_anchors.refresh\_time = nil**

**Return** int (default: nil)

Modify RFC5011 refresh timer to given value (not set by default), this will force trust anchors to be updated every N seconds periodically instead of relying on RFC5011 logic and TTLs. Example: 10 \* sec

**trust\_anchors.keep\_removed = 0**

**Return** int (default: 0)

How many Removed keys should be held in history (and key file) before being purged. Note: all Removed keys will be purged from key file after restarting the process.

**trust\_anchors.set\_insecure** (nta\_set)

**Parameters**

- **nta\_list** (*table*) – List of domain names (text format) representing NTAs.

When you use a domain name as an NTA, DNSSEC validation will be turned off at/below these names. Each function call replaces the previous NTA set. You can find the current active set in `trust_anchors.insecure` variable.

---

**Tip:** Use the `trust_anchors.negative = {}` alias for easier configuration.

---

Example output:

```
> trust_anchors.negative = { 'bad.boy', 'example.com' }
> trust_anchors.insecure
[1] => bad.boy
[2] => example.com
```

**trust\_anchors.add** (rr\_string)

**Parameters**

- **rr\_string** (*string*) – DS/DNSKEY records in presentation format (e.g. `. 3600 IN DS 19036 8 2 49AAC11...`)

Inserts DS/DNSKEY record(s) into current keyset. These will not be managed or updated, use it only for testing or if you have a specific use case for not using a keyfile.

Example output:

```
> trust_anchors.add('. 3600 IN DS 19036 8 2 49AAC11...')
```



## Modules configuration

The daemon provides an interface for dynamic loading of *daemon modules*.

**Tip:** Use declarative interface for module loading.

```
modules = {
    hints = {file = '/etc/hosts'}
}
```

Equals to:

```
modules.load('hints')
hints.config({file = '/etc/hosts'})
```

**modules.list()**

**Returns** List of loaded modules.

**modules.load(name)**

**Parameters**

- **name** (*string*) – Module name, e.g. “hints”

**Returns** boolean

Load a module by name.

**modules.unload(name)**

**Parameters**

- **name** (*string*) – Module name

**Returns** boolean

Unload a module by name.

## Cache configuration

The default cache in Knot DNS Resolver is persistent with LMDB backend, this means that the daemon doesn't lose the cached data on restart or crash to avoid cold-starts. The cache may be reused between cache daemons or manipulated from other processes, making for example synchronised load-balanced recursors possible.

**cache.size (number)**

Set the cache maximum size in bytes. Note that this is only a hint to the backend, which may or may not respect it. See [cache.open\(\)](#).

```
cache.size = 100 * MB -- equivalent to `cache.open(100 * MB)`
```

**cache.current\_size (number)**

Get the maximum size in bytes.

```
print(cache.current_size)
```

**cache.storage (string)**

Set the cache storage backend configuration, see [cache.backends\(\)](#) for more information. If the new storage configuration is invalid, it is not set.

```
cache.storage = 'lmdb://.'
```

### `cache.current_storage (string)`

Get the storage backend configuration.

```
print(cache.storage)
```

### `cache.backends ()`

**Returns** map of backends

The cache supports runtime-changeable backends, using the optional [RFC 3986](#) URI, where the scheme represents backend protocol and the rest of the URI backend-specific configuration. By default, it is a `lmdb` backend in working directory, i.e. `lmdb://`.

Example output:

```
[lmdb://] => true
```

### `cache.stats ()`

**return** table of cache counters

The cache collects counters on various operations (hits, misses, transactions, ...). This function call returns a table of cache counters that can be used for calculating statistics.

### `cache.open (max_size[, config_uri])`

#### Parameters

- **max\_size** (*number*) – Maximum cache size in bytes.

**Returns** boolean

Open cache with size limit. The cache will be reopened if already open. Note that the `max_size` cannot be lowered, only increased due to how cache is implemented.

---

**Tip:** Use `kB`, `MB`, `GB` constants as a multiplier, e.g. `100*MB`.

---

The cache supports runtime-changeable backends, see `cache.backends ()` for mor information and default. Refer to specific documentation of specific backends for configuration string syntax.

- `lmdb://`

As of now it only allows you to change the cache directory, e.g. `lmdb:///tmp/cachedir`.

### `cache.count ()`

**Returns** Number of entries in the cache or nil on error.

### `cache.close ()`

**Returns** boolean

Close the cache.

---

**Note:** This may or may not clear the cache, depending on the used backend. See `cache.clear ()`.

---

### `cache.stats ()`

Return table of statistics, note that this tracks all operations over cache, not just which queries were answered from cache or not.

Example:

```
print('Insertions:', cache.stats().insert)
```

**cache.max\_ttl** ([ttl])

**Parameters**

- **ttl** (*number*) – maximum cache TTL (default: 6 days)

**Returns** current maximum TTL

Get or set maximum cache TTL.

---

**Note:** The *ttl* value must be in range (*min\_ttl*, 4294967295).

---

**Warning:** This settings applies only to currently open cache, it will not persist if the cache is closed or reopened.

```
-- Get maximum TTL
cache.max_ttl()
518400
-- Set maximum TTL
cache.max_ttl(172800)
172800
```

**cache.min\_ttl** ([ttl])

**Parameters**

- **ttl** (*number*) – minimum cache TTL (default: 0)

**Returns** current maximum TTL

Get or set minimum cache TTL. Any entry inserted into cache with TTL lower than minimal will be overridden to minimum TTL. Forcing TTL higher than specified violates DNS standards, use with care.

---

**Note:** The *ttl* value must be in range  $<0, \text{max\_ttl}$ .

---

**Warning:** This settings applies only to currently open cache, it will not persist if the cache is closed or reopened.

```
-- Get minimum TTL
cache.min_ttl()
0
-- Set minimum TTL
cache.min_ttl(5)
5
```

**cache.prune** ([max\_count])

**Parameters**

- **max\_count** (*number*) – maximum number of items to be pruned at once (default: 65536)

**Returns** { pruned: int }

Prune expired/invalid records.

**cache.get** ([domain])

**Returns** list of matching records in cache

Fetches matching records from cache. The **domain** can either be:

- a domain name (e.g. "domain.cz")
- a wildcard (e.g. "\*.domain.cz")

The domain name fetches all records matching this name, while the wildcard matches all records at or below that name.

You can also use a special namespace "P" to purge NODATA/NXDOMAIN matching this name (e.g. "domain.cz P").

---

**Note:** This is equivalent to `cache['domain']` getter.

---

Examples:

```
-- Query cache for 'domain.cz'
cache['domain.cz']
-- Query cache for all records at/below 'insecure.net'
cache['*.insecure.net']
```

**cache.clear** ([domain])

**Returns** bool

Purge cache records. If the domain isn't provided, whole cache is purged. See `cache.get()` documentation for subtree matching policy.

Examples:

```
-- Clear records at/below 'bad.cz'
cache.clear('*.bad.cz')
-- Clear packet cache
cache.clear('*. P')
-- Clear whole cache
cache.clear()
```

## Timers and events

The timer represents exactly the thing described in the examples - it allows you to execute closures after specified time, or event recurrent events. Time is always described in milliseconds, but there are convenient variables that you can use - `sec`, `minute`, `hour`. For example, `5 * hour` represents five hours, or `5*60*60*100` milliseconds.

**event.after** (time, function)

**Returns** event id

Execute function after the specified time has passed. The first parameter of the callback is the event itself.

Example:

```
event.after(1 * minute, function() print('Hi!') end)
```

**event.recurrent** (interval, function)

**Returns** event id

Similar to `event.after()`, periodically execute function after interval passes.

Example:

```
msg_count = 0
event.recurrent(5 * sec, function(e)
  msg_count = msg_count + 1
  print('Hi #'..msg_count)
end)
```

**event.reschedule** (event\_id, timeout)

Reschedule a running event, it has no effect on canceled events. New events may reuse the event\_id, so the behaviour is undefined if the function is called after another event is started.

Example:

```
local interval = 1 * minute
event.after(1 * minute, function (ev)
  print('Good morning!')
  -- Halven the interval for each iteration
  interval = interval / 2
  event.reschedule(ev, interval)
end)
```

**event.cancel** (event\_id)

Cancel running event, it has no effect on already canceled events. New events may reuse the event\_id, so the behaviour is undefined if the function is called after another event is started.

Example:

```
e = event.after(1 * minute, function() print('Hi!') end)
event.cancel(e)
```

Watch for file descriptor activity. This allows embedding other event loops or simply firing events when a pipe endpoint becomes active. In another words, asynchronous notifications for daemon.

**event.socket** (fd, cb)

**Parameters**

- **fd** (*number*) – file descriptor to watch
- **cb** – closure or callback to execute when fd becomes active

**Returns** event id

Execute function when there is activity on the file descriptor and calls a closure with event id as the first parameter, status as second and number of events as third.

Example:

```
e = event.socket(0, function(e, status, nevents)
  print('activity detected')
end)
e.cancel(e)
```

## Asynchronous function execution

The *event* package provides a very basic mean for non-blocking execution - it allows running code when activity on a file descriptor is detected, and when a certain amount of time passes. It doesn't however provide an easy to use abstraction for non-blocking I/O. This is instead exposed through the *worker* package (if *cqueues* Lua package is installed in the system).

### **worker.coroutine** (function)

Start a new coroutine with given function (closure). The function can do I/O or run timers without blocking the main thread. See [cqueues](#) for documentation of possible operations and synchronisation primitives. The main limitation is that you can't wait for a finish of a coroutine from processing layers, because it's not currently possible to suspend and resume execution of processing layers.

Example:

```
worker.coroutine(function ()
  for i = 0, 10 do
    print('executing', i)
    worker.sleep(1)
  end
end)
```

### **worker.sleep** (seconds)

Pause execution of current function (asynchronously if running inside a worker coroutine).

When daemon is running in forked mode, each process acts independently. This is good because it reduces software complexity and allows for runtime scaling, but not ideal because of additional operational burden. For example, when you want to add a new policy, you'd need to add it to either put it in the configuration, or execute command on each process independently. The daemon simplifies this by promoting process group leader which is able to execute commands synchronously over forks.

Example:

```
worker.sleep(1)
```

### **map** (expr)

Run expression synchronously over all forks, results are returned as a table ordered as forks. Expression can be any valid expression in Lua.

Example:

```
-- Current instance only
hostname()
localhost
-- Mapped to forks
map 'hostname()'
[1] => localhost
[2] => localhost
-- Get worker ID from each fork
map 'worker.id'
[1] => 0
[2] => 1
-- Get cache stats from each fork
map 'cache.stats()'
[1] => {
  [hit] => 0
  [delete] => 0
  [miss] => 0
```

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```
[insert] => 0
}
[2] => {
  [hit] => 0
  [delete] => 0
  [miss] => 0
  [insert] => 0
}
```

## Scripting worker

Worker is a service over event loop that tracks and schedules outstanding queries, you can see the statistics or schedule new queries. It also contains information about specified worker count and process rank.

### **worker.count**

Return current total worker count (e.g. *1* for single-process)

### **worker.id**

Return current worker ID (starting from *0* up to *worker.count - 1*)

### **pid (number)**

Current worker process PID.

### **worker.stats ()**

Return table of statistics.

- `udp` - number of outbound queries over UDP
- `tcp` - number of outbound queries over TCP
- `ipv6` - number of outbound queries over IPv6
- `ipv4` - number of outbound queries over IPv4
- `timeout` - number of timeouted outbound queries
- `concurrent` - number of concurrent queries at the moment
- `queries` - number of inbound queries
- `dropped` - number of dropped inbound queries

Example:

```
print(worker.stats().concurrent)
```

## 1.2 Running supervised

Knot Resolver can run under a supervisor to allow for graceful restarts, watchdog process and socket activation. This way the supervisor binds to sockets and lends them to the resolver daemon. If the resolver terminates or is killed, the sockets remain open and no queries are dropped.

The watchdog process must notify `kresd` about active file descriptors, and `kresd` will automatically determine the socket type and bound address, thus it will appear as any other address. You should have a look at [real process managers](#).

The daemon also supports [systemd socket activation](#), it is automatically detected and requires no configuration on users' side.

See `kresd.systemd(7)` for details.

### 1.3 Enabling DNSSEC

The resolver supports DNSSEC including [RFC 5011](#) automated DNSSEC TA updates and [RFC 7646](#) negative trust anchors. To enable it, you need to provide trusted root keys. Bootstrapping of the keys is automated, and `kresd` fetches root trust anchors set over a [secure channel](#) from IANA. From there, it can perform [RFC 5011](#) automatic updates for you.

---

**Note:** Automatic bootstrap requires `luasocket` and `luasec` installed.

---

```
$ kresd -k root-new.keys # File for root keys
[ ta ] keyfile 'root-new.keys': doesn't exist, bootstrapping
[ ta ] Root trust anchors bootstrapped over https with pinned certificate.
      You SHOULD verify them manually against original source:
      https://www.iana.org/dnssec/files
[ ta ] Current root trust anchors are:
. 0 IN DS 19036 8 2 49AAC11D7B6F6446702E54A1607371607A1A41855200FD2CE1CDDE32F24E8FB5
. 0 IN DS 20326 8 2 E06D44B80B8F1D39A95C0B0D7C65D08458E880409BBC683457104237C7F8EC8D
[ ta ] next refresh for . in 24 hours
```

Alternatively, you can set it in configuration file with `trust_anchors.file = 'root.keys'`. If the file doesn't exist, it will be automatically populated with root keys validated using root anchors retrieved over HTTPS.

This is equivalent to using `unbound-anchor`:

```
$ unbound-anchor -a "root.keys" || echo "warning: check the key at this point"
$ echo "auto-trust-anchor-file: \"root.keys\"" >> unbound.conf
$ unbound -c unbound.conf
```

**Warning:** Bootstrapping of the root trust anchors is automatic, you are however **encouraged to check** the key over **secure channel**, as specified in [DNSSEC Trust Anchor Publication for the Root Zone](#). This is a critical step where the whole infrastructure may be compromised, you will be warned in the server log.

Configuration is described in *Trust anchors and DNSSEC*.

#### 1.3.1 Manually providing root anchors

The root anchors bootstrap may fail for various reasons, in this case you need to provide IANA or alternative root anchors. The format of the keyfile is the same as for Unbound or BIND and contains DS/DNSKEY records.

1. Check the current TA published on [IANA website](#)
2. Fetch current keys (DNSKEY), verify digests
3. Deploy them

```
$ kdig DNSKEY . @k.root-servers.net +noall +answer | grep "DNSKEY[[:space:]]257" >_
↪root.keys
$ ldns-key2ds -n root.keys # Only print to stdout
... verify that digest matches TA published by IANA ...
$ kresd -k root.keys
```



You've just enabled DNSSEC!

---

**Note:** Bootstrapping and automatic update need write access to keyfile directory. If you want to manage root anchors manually you should use `trust_anchors.add_file('root.keys', true)`.

---

## 1.4 CLI interface

The daemon features a CLI interface, type `help()` to see the list of available commands.

```
$ kresd /var/cache/knot-resolver
[system] started in interactive mode, type 'help()'
> cache.count()
53
```

### 1.4.1 Verbose output

If the verbose logging is compiled in, i.e. not turned off by `-DNOVERBOSELOG`, you can turn on verbose tracing of server operation with the `-v` option. You can also toggle it on runtime with `verbose(true|false)` command.

```
$ kresd -v
```

To run the daemon by hand, such as under `nohup`, use `-f 1` to start a single fork. For example:

```
$ nohup ./daemon/kresd -a 127.0.0.1 -f 1 -v &
```

## 1.5 Scaling out

The server can clone itself into multiple processes upon startup, this enables you to scale it on multiple cores. Multiple processes can serve different addresses, but still share the same working directory and cache. You can add, start and stop processes during runtime based on the load.

```
$ kresd -f 4 rundir > kresd.log &
$ kresd -f 2 rundir > kresd_2.log & # Extra instances
$ pstree $$ -g
bash(3533)—kresd(19212)—kresd(19212)
                |
                |—kresd(19212)
                |—kresd(19212)
                |—kresd(19399)—kresd(19399)
                |—pstree(19411)
$ kill 19399 # Kill group 2, former will continue to run
bash(3533)—kresd(19212)—kresd(19212)
                |
                |—kresd(19212)
                |—kresd(19212)
                |—pstree(19460)
```

---

**Note:** On recent Linux supporting `SO_REUSEPORT` (since 3.9, backported to RHEL 2.6.32) it is also able to bind to the same endpoint and distribute the load between the forked processes. If your OS doesn't support it, use only one daemon process.

---

Notice the absence of an interactive CLI. You can attach to the the consoles for each process, they are in `rundir/tty/PID`.

```
$ nc -U rundir/tty/3008 # or socat - UNIX-CONNECT:rundir/tty/3008
> cache.count()
53
```

The *direct output* of the CLI command is captured and sent over the socket, while also printed to the daemon standard outputs (for accountability). This gives you an immediate response on the outcome of your command. Error or debug logs aren't captured, but you can find them in the daemon standard outputs.

This is also a way to enumerate and test running instances, the list of files in `tty` corresponds to the list of running processes, and you can test the process for liveness by connecting to the UNIX socket.

## 1.6 Using CLI tools

- `kresd-host.lua` - a drop-in replacement for `host(1)` utility

Queries the DNS for information. The hostname is looked up for IP4, IP6 and mail.

Example:

```
$ kresd-host.lua -f root.key -v nic.cz
nic.cz. has address 217.31.205.50 (secure)
nic.cz. has IPv6 address 2001:1488:0:3::2 (secure)
nic.cz. mail is handled by 10 mail.nic.cz. (secure)
nic.cz. mail is handled by 20 mx.nic.cz. (secure)
nic.cz. mail is handled by 30 bh.nic.cz. (secure)
```

- `kresd-query.lua` - run the daemon in zero-configuration mode, perform a query and execute given callback.

This is useful for executing one-shot queries and hooking into the processing of the result, for example to check if a domain is managed by a certain registrar or if it's signed.

Example:

```
$ kresd-query.lua www.sub.nic.cz 'assert(kres.dname2str(req:resolved()).zone_cut.name) == "nic.cz.">' && echo "yes"
yes
$ kresd-query.lua -C 'trust_anchors.config("root.keys")' nic.cz
→ 'assert(req:resolved().flags.DNSSEC_WANT) '
$ echo $?
0
```

---

### Knot DNS Resolver modules

---

- *Static hints*
- *Statistics collector*
- *Query policies*
- *Views and ACLs*
- *Prefetching records*
- *HTTP/2 services*
- *DNS Application Firewall*
- *Graphite module*
- *Etc module*
- *DNS64*
- *Renumber*
- *DNS Cookies*
- *Version*
- *Workarounds*
- *Dnstap*
- *Signaling Trust Anchor Knowledge in DNSSEC*
- *Sentinel for Detecting Trusted Keys*
- *Priming module*
- *Serve stale*
- *System time skew detector*

- *Detect discontinuous jumps in the system time*

## 2.1 Static hints

This is a module providing static hints for forward records (A/AAAA) and reverse records (PTR). The records can be loaded from `/etc/hosts`-like files and/or added directly.

You can also use the module to change the root hints; they are used as a safety belt or if the root NS drops out of cache.

### 2.1.1 Examples

```
-- Load hints after iterator (so hints take precedence before caches)
modules = { 'hints > iterate' }
-- Add a custom hosts file
hints.add_hosts('hosts.custom')
-- Override the root hints
hints.root({
  ['j.root-servers.net.'] = { '2001:503:c27::2:30', '192.58.128.30' }
})
-- Add a custom hint
hints['foo.bar'] = '127.0.0.1'
```

---

**Note:** The `policy` module applies before `hints`, meaning e.g. that hints for special names ([RFC 6761#section-6](#)) like `localhost` or `test` will get shadowed by `policy` rules by default. That can be worked around e.g. by explicit `policy.PASS` action.

---

### 2.1.2 Properties

**hints.config** ([path])

**Parameters**

- **path** (*string*) – path to hosts-like file, default: no file

**Returns** { result: bool }

Clear any configured hints, and optionally load a hosts-like file as in `hints.add_hosts(path)`. (Root hints are not touched.)

**hints.add\_hosts** ([path])

**Parameters**

- **path** (*string*) – path to hosts-like file, default: `/etc/hosts`

Add hints from a host-like file.

**hints.get** (*hostname*)

**Parameters**

- **hostname** (*string*) – i.e. "localhost"

**Returns** { result: [address1, address2, ...] }

Return list of address record matching given name. If no hostname is specified, all hints are returned in the table format used by `hints.root()`.

**hints.set** (pair)

**Parameters**

- **pair** (*string*) – hostname address i.e. "localhost 127.0.0.1"

**Returns** { result: bool }

Add a hostname - address pair hint.

---

**Note:** If multiple addresses have been added for a name, all are returned in a forward query. If multiple names have been added to an address, the last one defined is returned in a corresponding PTR query.

---

**hints.del** (pair)

**Parameters**

- **pair** (*string*) – hostname address i.e. "localhost 127.0.0.1", or just hostname

**Returns** { result: bool }

Remove a hostname - address pair hint. If address is omitted, all addresses for the given name are deleted.

**hints.root** ()

**Returns** { ['a.root-servers.net.'] = { '1.2.3.4', '5.6.7.8', ... }, ... }

---

**Tip:** If no parameters are passed, returns current root hints set.

---

**hints.root\_file** (path)

Replace current root hints from a zonefile. If the path is omitted, the compiled-in path is used, i.e. the root hints are reset to the default.

**hints.root** (root\_hints)

**Parameters**

- **root\_hints** (*table*) – new set of root hints i.e. { ['name'] = 'addr', ... }

**Returns** { ['a.root-servers.net.'] = { '1.2.3.4', '5.6.7.8', ... }, ... }

Replace current root hints and return the current table of root hints.

Example:

```
> hints.root({
  ['l.root-servers.net.'] = '199.7.83.42',
  ['m.root-servers.net.'] = '202.12.27.33'
})
[l.root-servers.net.] => {
  [1] => 199.7.83.42
}
[m.root-servers.net.] => {
  [1] => 202.12.27.33
}
```

---

**Tip:** A good rule of thumb is to select only a few fastest root hints. The server learns RTT and NS quality over time, and thus tries all servers available. You can help it by preselecting the candidates.

---

## 2.2 Statistics collector

This module gathers various counters from the query resolution and server internals, and offers them as a key-value storage. Any module may update the metrics or simply hook in new ones.

```
-- Enumerate metrics
> stats.list()
[answer.cached] => 486178
[iterator.tcp] => 490
[answer.noerror] => 507367
[answer.total] => 618631
[iterator.udp] => 102408
[query.concurrent] => 149

-- Query metrics by prefix
> stats.list('iter')
[iterator.udp] => 105104
[iterator.tcp] => 490

-- Set custom metrics from modules
> stats['filter.match'] = 5
> stats['filter.match']
5

-- Fetch most common queries
> stats.frequent()
[1] => {
  [type] => 2
  [count] => 4
  [name] => cz.
}

-- Fetch most common queries (sorted by frequency)
> table.sort(stats.frequent(), function (a, b) return a.count > b.count end)

-- Show recently contacted authoritative servers
> stats.upstreams()
[2a01:618:404::1] => {
  [1] => 26 -- RTT
}
[128.241.220.33] => {
  [1] => 31 - RTT
}
```

### 2.2.1 Properties

**stats.get** (key)

**Parameters**

- **key** (*string*) – i.e. "answer.total"

**Returns** number

Return nominal value of given metric.

**stats.set** (key, val)

**Parameters**

- **key** (*string*) – i.e. "answer.total"
- **val** (*number*) – i.e. 5

Set nominal value of given metric.

**stats.list** ([prefix])

**Parameters**

- **prefix** (*string*) – optional metric prefix, i.e. "answer" shows only metrics beginning with "answer"

Outputs collected metrics as a JSON dictionary.

**stats.upstreams** ()

Outputs a list of recent upstreams and their RTT. It is sorted by time and stored in a ring buffer of a fixed size. This means it's not aggregated and readable by multiple consumers, but also that you may lose entries if you don't read quickly enough. The default ring size is 512 entries, and may be overridden on compile time by `-DUPSTREAMS_COUNT=X`.

**stats.frequent** ()

Outputs list of most frequent iterative queries as a JSON array. The queries are sampled probabilistically, and include subrequests. The list maximum size is 5000 entries, make diffs if you want to track it over time.

**stats.clear\_frequent** ()

Clear the list of most frequent iterative queries.

## 2.2.2 Built-in statistics

- `answer.total` - total number of answered queries
- `answer.cached` - number of queries answered from cache
- `answer.noerror` - number of **NOERROR** answers
- `answer.nodata` - number of **NOERROR**, but empty answers
- `answer.nxdomain` - number of **NXDOMAIN** answers
- `answer.servfail` - number of **SERVFAIL** answers
- `answer.1ms` - number of answers completed in 1ms
- `answer.10ms` - number of answers completed in 10ms
- `answer.50ms` - number of answers completed in 50ms
- `answer.100ms` - number of answers completed in 100ms
- `answer.250ms` - number of answers completed in 250ms
- `answer.500ms` - number of answers completed in 500ms
- `answer.1000ms` - number of answers completed in 1000ms

- `answer.1500ms` - number of answers completed in 1500ms
- `answer.slow` - number of answers that took more than 1500ms
- `query.edns` - number of queries with EDNS
- `query.dnssec` - number of queries with DNSSEC DO=1

## 2.3 Query policies

This module can block, rewrite, or alter inbound queries based on user-defined policies.

Each policy *rule* has two parts: a *filter* and an *action*. A *filter* selects which queries will be affected by the policy, and *action* which modifies queries matching the associated filter. Typically a rule is defined as follows: `filter(action(action parameters), filter parameters)`. For example, a filter can be `suffix` which matches queries whose suffix part is in specified set, and one of possible actions is `DENY`, which denies resolution. These are combined together into `policy.suffix(policy.DENY, {todname('badguy.example.')})`. The rule is effective when it is added into rule table using `policy.add()`, please see *Policy examples*.

By default, if no rule applies to a query, built-in rules for `special-use` and `locally-served` domain names are applied. These built-in rules can be overridden using action `PASS`, see *Policy examples* below.

### 2.3.1 Filters

A *filter* selects which queries will be affected by specified *action*. There are several policy filters available in the `policy.table`:

- `all(action)` - always applies the action
- `pattern(action, pattern)` - applies the action if QNAME matches a [regular expression](#)
- `suffix(action, table)` - applies the action if QNAME suffix matches one of suffixes in the table (useful for “is domain in zone” rules), uses [Aho-Corasick](#) string matching algorithm from [CloudFlare](#) (BSD 3-clause)
- `policy.suffix_common`
- `rpz` - implements a subset of [RPZ](#) in zonefile format. See below for details: `policy.rpz`.
- custom filter function

### 2.3.2 Actions

An *action* is function which modifies DNS query. There are several actions available in the `policy.table`:

- `PASS` - let the query pass through; it’s useful to make exceptions before wider rules
- `DENY` - reply `NXDOMAIN` authoritatively
- `DENY_MSG(msg)` - reply `NXDOMAIN` authoritatively and add explanatory message to additional section
- `DROP` - terminate query resolution and return `SERVFAIL` to the requestor
- `TC` - set `TC=1` if the request came through UDP, forcing client to retry with TCP
- `FORWARD(ip)` - resolve a query via forwarding to an IP while validating and caching locally;
- `TLS_FORWARD({ip, authentication})` - resolve a query via TLS connection forwarding to an IP while validating and caching locally; the parameter can be a single IP (string) or a lua list of up to four IPs.



- `STUB(ip)` - similar to `FORWARD(ip)` but *without* attempting DNSSEC validation. Each request may be either answered from cache or simply sent to one of the IPs with proxying back the answer.
- `MIRROR(ip)` - mirror query to given IP and continue solving it (useful for partial snooping); it's a chain action
- `REROUTE({{subnet,target}}, ...)` - reroute addresses in response matching given subnet to given target, e.g. `{'192.0.2.0/24', '127.0.0.0'}` will rewrite '192.0.2.55' to '127.0.0.55', see *renumber module* for more information.
- `QTRACE` - pretty-print DNS response packets into the log for the query and its sub-queries. It's useful for debugging weird DNS servers. It's a chain action.
- `FLAGS(set, clear)` - set and/or clear some flags for the query. There can be multiple flags to set/clear. You can just pass a single flag name (string) or a set of names. It's a chain action.

Most actions stop the policy matching on the query, but “chain actions” allow to keep trying to match other rules, until a non-chain action is triggered.

Also, it is possible to write your own action (i.e. Lua function). It is possible to implement complex heuristics, e.g. to deflect [Slow drip DNS attacks](#) or gray-list resolution of misbehaving zones.

**Warning:** The policy module currently only looks at whole DNS requests. The rules won't be re-applied e.g. when following CNAMEs.

**Note:** The module (and `kres`) expects domain names in wire format, not textual representation. So each label in name is prefixed with its length, e.g. “example.com” equals to `"\7example\3com"`. You can use convenience function `todname('example.com')` for automatic conversion.

### 2.3.3 Forwarding over TLS protocol (DNS-over-TLS)

Policy `TLS_FORWARD` allows you to forward queries using [Transport Layer Security](#) protocol, which hides the content of your queries from an attacker observing the network traffic. Further details about this protocol can be found in [RFC 7858](#) and [IETF draft dprive-dtls-and-tls-profiles](#).

Queries affected by `TLS_FORWARD` policy will always be resolved over TLS connection. Knot Resolver does not implement fallback to non-TLS connection, so if TLS connection cannot be established or authenticated according to the configuration, the resolution will fail.

To test this feature you need to either *configure Knot Resolver as DNS-over-TLS server*, or pick some public DNS-over-TLS server. Please see [DNS Privacy Project](#) homepage for list of public servers.

When multiple servers are specified, the one with the lowest round-trip time is used.

#### TLS Examples

```
modules = { 'policy' }
-- forward all queries over TLS to the specified server
policy.add(policy.all(policy.TLS_FORWARD({'192.0.2.1', pin_sha256='YQ=='})))
-- for brevity, other TLS examples omit policy.add(policy.all())
-- single server authenticated using its certificate pin_sha256
  policy.TLS_FORWARD({'192.0.2.1', pin_sha256='YQ=='}) -- pin_sha256 is base64-
  ↪ encoded
-- single server using non-standard port
```

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```

policy.TLS_FORWARD({'192.0.2.1@443', pin_sha256='YQ=='}) -- use @ or # to
↪specify port
-- single server with multiple valid pins (e.g. anycast)
policy.TLS_FORWARD({'192.0.2.1', pin_sha256={'YQ==', 'Wg=='}})
-- multiple servers, each with own authenticator
policy.TLS_FORWARD({ -- please note that { here starts list of servers
    {'192.0.2.1', pin_sha256='Wg=='},
    -- server must present certificate issued by specified CA and hostname must
↪match
    {'2001:DB8::d0c', hostname='res.example.', ca_file='/etc/knot-resolver/tlsca.
↪crt'}
})

```

### 2.3.4 Policy examples

```

-- Whitelist 'www[0-9].badboy.cz'
policy.add(policy.pattern(policy.PASS, '\4www[0-9]\6badboy\2cz'))
-- Block all names below badboy.cz
policy.add(policy.suffix(policy.DENY, {todname('badboy.cz.')}))
-- Custom rule
policy.add(function (req, query)
    if query.qname():find('%d.%d.%d.224\7in-addr\4arpa') then
        return policy.DENY
    end
end)
-- Disallow ANY queries
policy.add(function (req, query)
    if query.stype == kres.type.ANY then
        return policy.DROP
    end
end)
-- Enforce local RPZ
policy.add(policy.rpz(policy.DENY, 'blacklist.rpz'))
-- Forward all queries below 'company.se' to given resolver
policy.add(policy.suffix(policy.FORWARD('192.168.1.1'), {todname('company.se.')}))
-- Forward all queries matching pattern
policy.add(policy.pattern(policy.FORWARD('2001:DB8::1'), '\4bad[0-9]\2cz'))
-- Forward all queries (to public resolvers https://www.nic.cz/odvr)
policy.add(policy.all(policy.FORWARD({'2001:678:1::206', '193.29.206.206'})))
-- Print all responses with matching suffix
policy.add(policy.suffix(policy.QTRACE, {todname('rhybar.cz.')}))
-- Print all responses
policy.add(policy.all(policy.QTRACE))
-- Mirror all queries and retrieve information
local rule = policy.add(policy.all(policy.MIRROR('127.0.0.2')))
-- Print information about the rule
print(string.format('id: %d, matched queries: %d', rule.id, rule.count))
-- Reroute all addresses found in answer from 192.0.2.0/24 to 127.0.0.x
-- this policy is enforced on answers, therefore 'postrule'
local rule = policy.add(policy.REROUTE({'192.0.2.0/24', '127.0.0.0'}, true))
-- Delete rule that we just created
policy.del(rule.id)

```

### 2.3.5 Additional properties

Most properties (actions, filters) are described above.

`policy.add` (rule, postrule)

**Parameters**

- **rule** – added rule, i.e. `policy.pattern(policy.DENY, '[0-9]+\2cz')`
- **postrule** – boolean, if true the rule will be evaluated on answer instead of query

**Returns** rule description

Add a new policy rule that is executed either on queries or answers, depending on the `postrule` parameter. You can then use the returned rule description to get information and unique identifier for the rule, as well as match count.

`policy.del` (id)

**Parameters**

- **id** – identifier of a given rule

**Returns** boolean

Remove a rule from policy list.

`policy.suffix_common` (action, suffix\_table[, common\_suffix])

**Parameters**

- **action** – action if the pattern matches QNAME
- **suffix\_table** – table of valid suffixes
- **common\_suffix** – common suffix of entries in `suffix_table`

Like `suffix match`, but you can also provide a common suffix of all matches for faster processing (nil otherwise). This function is faster for small suffix tables (in the order of “hundreds”).

`policy.rpz` (action, path[, format])

**Parameters**

- **action** – the default action for match in the zone (e.g. `RH-value .`)
- **path** – path to zone file | database

Enforce **RPZ** rules. This can be used in conjunction with published blacklist feeds. The **RPZ** operation is well described in this [Jan-Piet Mens’s post](#), or the [Pro DNS and BIND](#) book. Here’s compatibility table:

Policy Action	RH Value	Support
NXDOMAIN	.	<b>yes</b>
NODATA	*.	<i>partial</i> , implemented as NXDOMAIN
Unchanged	<code>rpz-passthru.</code>	<b>yes</b>
Nothing	<code>rpz-drop.</code>	<b>yes</b>
Truncated	<code>rpz-tcp-only.</code>	<b>yes</b>
Modified	anything	no

Policy Trigger	Support
QNAME	yes
CLIENT-IP	<i>partial, may be done with views</i>
IP	no
NSDNAME	no
NS-IP	no

`policy.todnames` ({name, ...})

**Param** names table of domain names in textual format

Returns table of domain names in wire format converted from strings.

```
-- Convert single name
assert(todname('example.com') == '\7example\3com\0')
-- Convert table of names
policy.todnames({'example.com', 'me.cz'})
{ '\7example\3com\0', '\2me\2cz\0' }
```

This module is enabled by default because it implements mandatory **RFC 6761** logic. For debugging purposes you can add `modules.unload('policy')` to your config to unload the module.

## 2.4 Views and ACLs

The *policy* module implements policies for global query matching, e.g. solves “how to react to certain query”. This module combines it with query source matching, e.g. “who asked the query”. This allows you to create personalized blacklists, filters and ACLs, sort of like ISC BIND views.

There are two identification mechanisms:

- `subnet` - identifies the client based on his subnet
- `tsig` - identifies the client based on a TSIG key

You can combine this information with *policy* rules.

```
view:addr('10.0.0.1', policy.suffix(policy.TC, {'\7example\3com'}))
```

This will force given client subnet to TCP for names in `example.com`. You can combine view selectors with **RPZ** to create personalized filters for example.

### 2.4.1 Example configuration

```
-- Load modules
modules = { 'policy', 'view' }
-- Whitelist queries identified by TSIG key
view:tsig('\5mykey', function (req, qry) return policy.PASS end)
-- Block local clients (ACL like)
view:addr('127.0.0.1', function (req, qry) return policy.DENY end))
-- Drop queries with suffix match for remote client
view:addr('10.0.0.0/8', policy.suffix(policy.DROP, {'\3xxx'}))
-- RPZ for subset of clients
view:addr('192.168.1.0/24', policy.rpz(policy.PASS, 'whitelist.rpz'))
-- Forward all queries from given subnet to proxy
```

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```
view:addr('10.0.0.0/8', policy.all(policy.FORWARD('2001:DB8::1')))
-- Drop everything that hasn't matched
view:addr('0.0.0.0/0', function (req, qry) return policy.DROP end)
```

## 2.4.2 Properties

**view:addr** (subnet, rule)

### Parameters

- **subnet** – client subnet, i.e. 10.0.0.1
- **rule** – added rule, i.e. `policy.pattern(policy.DENY, '[0-9]+\2cz')`

Apply rule to clients in given subnet.

**view:tsig** (key, rule)

### Parameters

- **key** – client TSIG key domain name, i.e. \5mykey
- **rule** – added rule, i.e. `policy.pattern(policy.DENY, '[0-9]+\2cz')`

Apply rule to clients with given TSIG key.

**Warning:** This just selects rule based on the key name, it doesn't verify the key or signature yet.

## 2.5 Prefetching records

The module refreshes records that are about to expire when they're used (having less than 1% of original TTL). This improves latency for frequently used records, as they are fetched in advance.

It is also able to learn usage patterns and repetitive queries that the server makes. For example, if it makes a query every day at 18:00, the resolver expects that it is needed by that time and prefetches it ahead of time. This is helpful to minimize the perceived latency and keeps the cache hot.

**Tip:** The tracking window and period length determine memory requirements. If you have a server with relatively fast query turnover, keep the period low (hour for start) and shorter tracking window (5 minutes). For personal slower resolver, keep the tracking window longer (i.e. 30 minutes) and period longer (a day), as the habitual queries occur daily. Experiment to get the best results.

### 2.5.1 Example configuration

**Warning:** This module requires 'stats' module to be present and loaded.

```
modules = {
  predict = {
    window = 15, -- 15 minutes sampling window
    period = 6*(60/15) -- track last 6 hours
  }
}
```

Defaults are 15 minutes window, 6 hours period.

---

**Tip:** Use period 0 to turn off prediction and just do prefetching of expiring records. That works even without the ‘stats’ module.

---

### 2.5.2 Exported metrics

To visualize the efficiency of the predictions, the module exports following statistics.

- `predict.epoch` - current prediction epoch (based on time of day and sampling window)
- `predict.queue` - number of queued queries in current window
- `predict.learned` - number of learned queries in current window

### 2.5.3 Properties

`predict.config` ({ window = 15, period = 24})

Reconfigure the predictor to given tracking window and period length. Both parameters are optional. Window length is in minutes, period is a number of windows that can be kept in memory. e.g. if a window is 15 minutes, a period of “24” means 6 hours.

## 2.6 HTTP/2 services

This is a module that does the heavy lifting to provide an HTTP/2 enabled server that supports TLS by default and provides endpoint for other modules in order to enable them to export restful APIs and websocket streams. One example is statistics module that can stream live metrics on the website, or publish metrics on request for Prometheus scraper.

The server allows other modules to either use default endpoint that provides built-in webpage, restful APIs and websocket streams, or create new endpoints.

### 2.6.1 Example configuration

By default, the web interface starts HTTPS/2 on port 8053 using an ephemeral certificate that is valid for 90 days and is automatically renewed. It is of course self-signed, so you should use your own judgement before exposing it to the outside world. Why not use something like [Let’s Encrypt](#) for starters?

```
-- Load HTTP module with defaults
modules = {
  http = {
    host = 'localhost',
    port = 8053,
```

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```

    geoip = 'GeoLite2-City.mmdb' -- Optional, see
    -- e.g. https://dev.maxmind.com/geoip/geoip2/geolite2/
    -- and install mmdblua library
  }
}

```

Now you can reach the web services and APIs, done!

```

$ curl -k https://localhost:8053
$ curl -k https://localhost:8053/stats

```

It is possible to disable HTTPS altogether by passing `cert = false` option. While it's not recommended, it could be fine for localhost tests as, for example, Safari doesn't allow WebSockets over HTTPS with a self-signed certificate. Major drawback is that current browsers won't do HTTP/2 over insecure connection.

```

http = {
  host = 'localhost',
  port = 8053,
  cert = false,
}

```

If you want to provide your own certificate and key, you're welcome to do so:

```

http = {
  host = 'localhost',
  port = 8053,
  cert = 'mycert.crt',
  key = 'mykey.key',
}

```

The format of both certificate and key is expected to be PEM, e.g. equivalent to the outputs of following:

```

openssl ecparam -genkey -name prime256v1 -out mykey.key
openssl req -new -key mykey.key -out csr.pem
openssl req -x509 -days 90 -key mykey.key -in csr.pem -out mycert.crt

```

## 2.6.2 Built-in services

The HTTP module has several built-in services to use.

Endpoint	Service	Description
/stats	Statistics/metrics	Exported metrics in JSON.
/metrics	Prometheus metrics	Exported metrics for <a href="#">Prometheus</a>
/feed	Most frequent queries	List of most frequent queries in JSON.
/trace/:name/:type	Tracking	Trace resolution of the query and return the verbose logs.

## 2.6.3 Enabling Prometheus metrics endpoint

The module exposes `/metrics` endpoint that serves internal metrics in [Prometheus](#) text format. You can use it out of the box:

```
$ curl -k https://localhost:8053/metrics | tail
# TYPE latency_histogram
latency_bucket{le=10} 2.000000
latency_bucket{le=50} 2.000000
latency_bucket{le=100} 2.000000
latency_bucket{le=250} 2.000000
latency_bucket{le=500} 2.000000
latency_bucket{le=1000} 2.000000
latency_bucket{le=1500} 2.000000
latency_bucket{le=+Inf} 2.000000
latency_count 2.000000
latency_sum 11.000000
```

### 2.6.4 Tracing requests

With the `/trace` endpoint you can trace various aspects of the request execution. The basic mode allows you to resolve a query and trace verbose logs (and messages received):

```
$ curl http://localhost:8053/trace/e.root-servers.net
[ 8138] [iter] 'e.root-servers.net.' type 'A' created outbound query, parent id 0
[ 8138] [ rc ] => rank: 020, lowest 020, e.root-servers.net. A
[ 8138] [ rc ] => satisfied from cache
[ 8138] [iter] <= answer received:
;; ->>HEADER<<- opcode: QUERY; status: NOERROR; id: 8138
;; Flags: qr aa QUERY: 1; ANSWER: 0; AUTHORITY: 0; ADDITIONAL: 0

;; QUESTION SECTION
e.root-servers.net.          A

;; ANSWER SECTION
e.root-servers.net. 3556353 A          192.203.230.10

[ 8138] [iter] <= rcode: NOERROR
[ 8138] [resl] finished: 4, queries: 1, mempool: 81952 B
```

### 2.6.5 How to expose services over HTTP

The module provides a table endpoints of already existing endpoints, it is free for reading and writing. It contains tables describing a triplet - {mime, on\_serve, on\_websocket}. In order to register a new service, simply add it to the table:

```
http.endpoints['/health'] = {'application/json',
function (h, stream)
  -- API call, return a JSON table
  return {state = 'up', uptime = 0}
end,
function (h, ws)
  -- Stream current status every second
  local ok = true
  while ok do
    local push = tojson('up')
    ok = ws:send(tojson({'up'}))
    require('cqueues').sleep(1)
  end
end
```

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```

-- Finalize the WebSocket
ws:close()
end}

```

Then you can query the API endpoint, or tail the WebSocket using curl.

```

$ curl -k http://localhost:8053/health
{"state":"up","uptime":0}
$ curl -k -i -N -H "Connection: Upgrade" -H "Upgrade: websocket" -H "Host:
↪localhost:8053/health" -H "Sec-WebSocket-Key: nope" -H "Sec-WebSocket-Version: 13"
↪https://localhost:8053/health
HTTP/1.1 101 Switching Protocols
upgrade: websocket
sec-websocket-accept: eg18mwU7CDRGUF1Q+EJwPM335eM=
connection: upgrade

?["up"]?["up"]?["up"]

```

Since the stream handlers are effectively coroutines, you are free to keep state and yield using cqueues. This is especially useful for WebSockets, as you can stream content in a simple loop instead of chains of callbacks.

Last thing you can publish from modules are “*snippets*”. Snippets are plain pieces of HTML code that are rendered at the end of the built-in webpage. The snippets can be extended with JS code to talk to already exported restful APIs and subscribe to WebSockets.

```

http.snippets['/health'] = {'Health service', '<p>UP!</p>'}

```

## 2.6.6 How to expose RESTful services

A RESTful service is likely to respond differently to different type of methods and requests, there are three things that you can do in a service handler to send back results. First is to just send whatever you want to send back, it has to respect MIME type that the service declared in the endpoint definition. The response code would then be 200 OK, any non-string responses will be packed to JSON. Alternatively, you can respond with a number corresponding to the HTTP response code or send headers and body yourself.

```

-- Our upvalue
local value = 42

-- Expose the service
http.endpoints['/service'] = {'application/json',
function (h, stream)
  -- Get request method and deal with it properly
  local m = h:get(':method')
  local path = h:get(':path')
  log('[service] method %s path %s', m, path)
  -- Return table, response code will be '200 OK'
  if m == 'GET' then
    return {key = path, value = value}
  -- Save body, perform check and either respond with 505 or 200 OK
  elseif m == 'POST' then
    local data = stream:get_body_as_string()
    if not tonumber(data) then
      return 500, 'Not a good request'
    end
    value = tonumber(data)
  end
end}

```

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```

-- Unsupported method, return 405 Method not allowed
else
    return 405, 'Cannot do that'
end
end}

```

In some cases you might need to send back your own headers instead of default provided by HTTP handler, you can do this, but then you have to return `false` to notify handler that it shouldn't try to generate a response.

```

local headers = require('http.headers')
function (h, stream)
    -- Send back headers
    local hsend = headers.new()
    hsend:append(':status', '200')
    hsend:append('content-type', 'binary/octet-stream')
    assert(stream:write_headers(hsend, false))
    -- Send back data
    local data = 'binary-data'
    assert(stream:write_chunk(data, true))
    -- Disable default handler action
    return false
end

```

## 2.6.7 How to expose more interfaces

Services exposed in the previous part share the same external interface. This means that it's either accessible to the outside world or internally, but not one or another. This is not always desired, i.e. you might want to offer DNS/HTTPS to everyone, but allow application firewall configuration only on localhost. `http` module allows you to create additional interfaces with custom endpoints for this purpose.

```

http.interface('127.0.0.1', 8080, {
    ['/conf'] = {'application/json', function (h, stream) print('configuration API
↔') end},
    ['/private'] = {'text/html', static_page},
})

```

This way you can have different internal-facing and external-facing services at the same time.

## 2.6.8 Dependencies

- `lua-http` ( $\geq 0.1$ ) available in LuaRocks

If you're installing via Homebrew on OS X, you need OpenSSL too.

```

$ brew update
$ brew install openssl
$ brew link openssl --force # Override system OpenSSL

```

Any other system can install from LuaRocks directly:

```

$ luarocks install http

```

- `mmdblua` available in LuaRocks

```
$ luarocks install --server=https://luarocks.org/dev mmdblua
$ curl -O https://geolite.maxmind.com/download/geoip/database/GeoLite2-
↪City.mmdb.gz
$ gzip -d GeoLite2-City.mmdb.gz
```

## 2.7 DNS Application Firewall

This module is a high-level interface for other powerful filtering modules and DNS views. It provides an easy interface to apply and monitor DNS filtering rules and a persistent memory for them. It also provides a restful service interface and an HTTP interface.

### 2.7.1 Example configuration

Firewall rules are declarative and consist of filters and actions. Filters have field operator operand notation (e.g. `qname = example.com`), and may be chained using AND/OR keywords. Actions may or may not have parameters after the action name.

```
-- Let's write some daft rules!
modules = { 'daf' }

-- Block all queries with QNAME = example.com
daf.add 'qname = example.com deny'

-- Filters can be combined using AND/OR...
-- Block all queries with QNAME match regex and coming from given subnet
daf.add 'qname ~ %w+.example.com AND src = 192.0.2.0/24 deny'

-- We also can reroute addresses in response to alternate target
-- This reroutes 1.2.3.4 to localhost
daf.add 'src = 127.0.0.0/8 reroute 192.0.2.1-127.0.0.1'

-- Subnets work too, this reroutes a whole subnet
-- e.g. 192.0.2.55 to 127.0.0.55
daf.add 'src = 127.0.0.0/8 reroute 192.0.2.0/24-127.0.0.0'

-- This rewrites all A answers for 'example.com' from
-- whatever the original address was to 127.0.0.2
daf.add 'src = 127.0.0.0/8 rewrite example.com A 127.0.0.2'

-- Mirror queries matching given name to DNS logger
daf.add 'qname ~ %w+.example.com mirror 127.0.0.2'
daf.add 'qname ~ example-%d.com mirror 127.0.0.3@5353'

-- Forward queries from subnet
daf.add 'src = 127.0.0.1/8 forward 127.0.0.1@5353'
-- Forward to multiple targets
daf.add 'src = 127.0.0.1/8 forward 127.0.0.1@5353,127.0.0.2@5353'

-- Truncate queries based on destination IPs
daf.add 'dst = 192.0.2.51 truncate'

-- Disable a rule
daf.disable 2
```

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```
-- Enable a rule
daf.enable 2
-- Delete a rule
daf.del 2
```

If you're not sure what firewall rules are in effect, see `daf.rules`:

```
-- Show active rules
> daf.rules
[1] => {
  [rule] => {
    [count] => 42
    [id] => 1
    [cb] => function: 0x1a3eda38
  }
  [info] => qname = example.com AND src = 127.0.0.1/8 deny
  [policy] => function: 0x1a3eda38
}
[2] => {
  [rule] => {
    [suspended] => true
    [count] => 123522
    [id] => 2
    [cb] => function: 0x1a3ede88
  }
  [info] => qname ~ %w+.facebook.com AND src = 127.0.0.1/8 deny...
  [policy] => function: 0x1a3ede88
}
```

## 2.7.2 Web interface

If you have *HTTP/2* loaded, the firewall automatically loads as a snippet. You can create, track, suspend and remove firewall rules from the web interface. If you load both modules, you have to load *daf* after *http*.

## 2.7.3 RESTful interface

The module also exports a RESTful API for operations over rule chains.

URL	HTTP Verb	Action
/daf	GET	Return JSON list of active rules.
/daf	POST	Insert new rule, rule string is expected in body. Returns rule information in JSON.
/daf/<id>	GET	Retrieve a rule matching given ID.
/daf/<id>	DELETE	Delete a rule matching given ID.
/daf/<id>/<prop>/<val>	PATCH	Modify given rule, for example /daf/3/active/false suspends rule 3.

This interface is used by the web interface for all operations, but you can also use it directly for testing.

```
# Get current rule set
$ curl -s -X GET http://localhost:8053/daf | jq .
{}
```

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```

# Create new rule
$ curl -s -X POST -d "src = 127.0.0.1 pass" http://localhost:8053/daf | jq .
{
  "count": 0,
  "active": true,
  "info": "src = 127.0.0.1 pass",
  "id": 1
}

# Disable rule
$ curl -s -X PATCH http://localhost:8053/daf/1/active/false | jq .
true

# Retrieve a rule information
$ curl -s -X GET http://localhost:8053/daf/1 | jq .
{
  "count": 4,
  "active": true,
  "info": "src = 127.0.0.1 pass",
  "id": 1
}

# Delete a rule
$ curl -s -X DELETE http://localhost:8053/daf/1 | jq .
true

```

## 2.8 Graphite module

The module sends statistics over the [Graphite](#) protocol to either [Graphite](#), [Metronome](#), [InfluxDB](#) or any compatible storage. This allows powerful visualization over metrics collected by Knot DNS Resolver.

**Tip:** The Graphite server is challenging to get up and running, [InfluxDB](#) combined with [Grafana](#) are much easier, and provide richer set of options and available front-ends. [Metronome](#) by PowerDNS alternatively provides a mini-graphite server for much simpler setups.

### 2.8.1 Example configuration

Only the `host` parameter is mandatory.

By default the module uses UDP so it doesn't guarantee the delivery, set `tcp = true` to enable Graphite over TCP. If the TCP consumer goes down or the connection with Graphite is lost, resolver will periodically attempt to reconnect with it.

```

modules = {
  graphite = {
    prefix = hostname(), -- optional metric prefix
    host = '127.0.0.1', -- graphite server address
    port = 2003, -- graphite server port
    interval = 5 * sec, -- publish interval
    tcp = false -- set to true if want TCP mode
  }
}

```

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```
}  
}
```

The module supports sending data to multiple servers at once.

```
modules = {  
  graphite = {  
    host = { '127.0.0.1', '1.2.3.4', '::1' },  
  }  
}
```

## 2.8.2 Dependencies

- `luasocket` available in LuaRocks

```
$ luarocks install luasocket
```

## 2.9 Etcd module

The module connects to Etcd peers and watches for configuration change. By default, the module looks for the subtree under `/knot-resolver` directory, but you can change this [in the configuration](#).

The subtree structure corresponds to the configuration variables in the declarative style.

```
$ etcdctl set /knot-resolvevr/net/127.0.0.1 53  
$ etcdctl set /knot-resolver/cache/size 10000000
```

Configures all listening nodes to following configuration:

```
net = { '127.0.0.1' }  
cache.size = 10000000
```

### 2.9.1 Example configuration

```
modules = {  
  etcd = {  
    prefix = '/knot-resolver',  
    peer = 'http://127.0.0.1:7001'  
  }  
}
```

**Warning:** Work in progress!

### 2.9.2 Dependencies

- `lua-etcd` available in LuaRocks

```
$ luarocks install etcd --from=https://mah0x211.github.io/rocks/
```

## 2.10 DNS64

The module for [RFC 6147](#) DNS64 AAAA-from-A record synthesis, it is used to enable client-server communication between an IPv6-only client and an IPv4-only server. See the well written [introduction](#) in the PowerDNS documentation.

**Warning:** The module currently won't work well with policy.STUB.

**Tip:** The A record sub-requests will be DNSSEC secured, but the synthetic AAAA records can't be. Make sure the last mile between stub and resolver is secure to avoid spoofing.

### 2.10.1 Example configuration

```
-- Load the module with a NAT64 address
modules = { dns64 = 'fe80::21b:77ff:0:0' }
-- Reconfigure later
dns64.config('fe80::21b:aabb:0:0')
```

## 2.11 Renumber

The module renumbers addresses in answers to different address space. e.g. you can redirect malicious addresses to a blackhole, or use private address ranges in local zones, that will be remapped to real addresses by the resolver.

**Warning:** While requests are still validated using DNSSEC, the signatures are stripped from final answer. The reason is that the address synthesis breaks signatures. You can see whether an answer was valid or not based on the AD flag.

### 2.11.1 Example configuration

```
modules = {
  renumber = {
    -- Source subnet, destination subnet
    {'10.10.10.0/24', '192.168.1.0'},
    -- Remap /16 block to localhost address range
    {'166.66.0.0/16', '127.0.0.0'}
  }
}
```

## 2.12 DNS Cookies

The module performs most of the [RFC 7873](#) DNS cookies functionality. Its main purpose is to check the cookies of inbound queries and responses. It is also used to alter the behaviour of the cookie functionality.

## 2.12.1 Example Configuration

```
-- Load the module before the 'iterate' layer.
modules = {
    'cookies < iterate'
}

-- Configure the client part of the resolver. Set 8 bytes of the client
-- secret and choose the hashing algorithm to be used.
-- Use a string composed of hexadecimal digits to set the secret.
cookies.config { client_secret = '0123456789ABCDEF',
                 client_cookie_alg = 'FNV-64' }

-- Configure the server part of the resolver.
cookies.config { server_secret = 'FEDCBA9876543210',
                 server_cookie_alg = 'FNV-64' }

-- Enable client cookie functionality. (Add cookies into outbound
-- queries.)
cookies.config { client_enabled = true }

-- Enable server cookie functionality. (Handle cookies in inbound
-- requests.)
cookies.config { server_enabled = true }
```

---

**Tip:** If you want to change several parameters regarding the client or server configuration then do it within a single `cookies.config()` invocation.

---

**Warning:** The module must be loaded before any other module that has direct influence on query processing and response generation. The module must be able to intercept an incoming query before the processing of the actual query starts. It must also be able to check the cookies of inbound responses and eventually discard them before they are handled by other functional units.

## 2.12.2 Properties

`cookies.config` (configuration)

### Parameters

- **configuration** (*table*) – part of cookie configuration to be changed, may be called without parameter

**Returns** JSON dictionary containing current configuration

The function may be called without any parameter. In such case it only returns current configuration. The returned JSON also contains available algorithm choices.

## 2.12.3 Dependencies

- `Nettle` required for HMAC-SHA256



## 2.13 Version

Module checks for new version and CVE, and issues warning messages.

### 2.13.1 Configuration

```
version.config(2*day)
-- configure period of check (defaults to 1*day)
```

### 2.13.2 Running

```
modules.load("version")
```

## 2.14 Workarounds

A simple module that alters resolver behavior on specific broken sub-domains. Currently it mainly disables case randomization on them.

### 2.14.1 Running

```
modules = { 'workarounds < iterate' }
```

## 2.15 Dnstap

Dnstap module currently supports logging dns responses to a unix socket in dnstap format using fstrm framing library. The unix socket and the socket reader should be present before starting kresd.

### 2.15.1 Configuration

Tunables:

- `socket_path`: the the unix socket file where dnstap messages will be sent
- `log_responses`: if true responses in wire format will be logged

```
modules = {
  dnstap = {
    socket_path = "/tmp/dnstap.sock",
    log_responses = true
  }
}
```

## 2.16 Signaling Trust Anchor Knowledge in DNSSEC

The module for Signaling Trust Anchor Knowledge in DNSSEC Using Key Tag Query, implemented according to RFC 8145 section 5.

This feature allows validating resolvers to signal to authoritative servers which keys are referenced in their chain of trust. The data from such signaling allow zone administrators to monitor the progress of rollovers in a DNSSEC-signed zone.

This mechanism serve to measure the acceptance and use of new DNSSEC trust anchors and key signing keys (KSKs). This signaling data can be used by zone administrators as a gauge to measure the successful deployment of new keys. This is of particular interest for the DNS root zone in the event of key and/or algorithm rollovers that rely on RFC 5011 to automatically update a validating DNS resolver's trust anchor.

This module is enabled by default. You may use `modules.unload('ta_signal_query')` in your configuration.

## 2.17 Sentinel for Detecting Trusted Keys

The module implementing Sentinel for Detecting Trusted Keys in DNSSEC according to [draft-ietf-dnsop-kskroll-sentinel-00](#).

This feature allows users of validating resolver to detect which root keys are configured in their chain of trust. The data from such signaling are necessary to monitor the progress of the DNSSEC root key rollover.

This module is enabled by default and we urge users not to disable it. If it is absolutely necessary you may add `modules.unload('ta_sentinel')` to your configuration to disable it.

## 2.18 Priming module

The module for Initializing a DNS Resolver with Priming Queries implemented according to RFC 8109. Purpose of the module is to keep up-to-date list of root DNS servers and associated IP addresses.

Result of successful priming query replaces root hints distributed with the resolver software. Unlike other DNS resolvers, Knot Resolver caches result of priming query on disk and keeps the data between restarts until TTL expires.

This module is enabled by default and it is not recommended to disable it. For debugging purposes you may disable the module by appending `modules.unload('priming')` to your configuration.

## 2.19 Serve stale

Demo module that allows using timed-out records in case kresd is unable to contact upstream servers.

By default it allows stale-ness by up to one day, after roughly four seconds trying to contact the servers. It's quite configurable/flexible; see the beginning of the module source for details. See also the RFC [draft](#) (not fully followed).

### 2.19.1 Running

```
modules = { 'serve_stale < cache' }
```

## 2.20 System time skew detector

This module compares local system time with inception and expiration time bounds in DNSSEC signatures for . NS records. If the local system time is outside of these bounds, it is likely a misconfiguration which will cause all DNSSEC validation (and resolution) to fail.

In case of mismatch, a warning message will be logged to help with further diagnostics.

**Warning:** Information printed by this module can be forged by a network attacker! System administrator **MUST** verify values printed by this module and fix local system time using a trusted source.

This module is useful for debugging purposes. It runs only once during resolver start does not anything after that. It is enabled by default. You may disable the module by appending `modules.unload('detect_time_skew')` to your configuration.

## 2.21 Detect discontinuous jumps in the system time

This module detect discontinuous jumps in the system time when resolver is running. It clears cache when a significant backward time jumps occurs.

Time jumps are usually created by NTP time change or by admin intervention. These change can affect cache records as they store timestamp and TTL in real time.

If you want to preserve cache during time travel you should disable this module by `modules.unload('detect_time_jump')`.

Due to the way monotonic system time works on typical systems, suspend-resume cycles will be perceived as forward time jumps, but this direction of shift does not have the risk of using records beyond their intended TTL, so forward jumps do not cause erasing the cache.



### 3.1 Installing from packages

The resolver is packaged for Debian, Fedora+EPEL, Ubuntu, Docker, NixOS/NixPkgs, FreeBSD, HomeBrew, and Turris Omnia. Some of these are maintained directly by the knot-resolver team.

Refer to [project page](#) for information about installing from packages. If packages are not available for your OS, see following sections to see how you can build it from sources (or package it), or use official [Docker images](#).

### 3.2 Platform considerations

Project	Platforms	Compatibility notes
daemon	UNIX-like <sup>1</sup>	C99, <a href="#">libuv</a> provides portable I/O
library	UNIX-like	<a href="#">MSVC</a> not supported, needs <a href="#">MinGW</a>
modules	<i>varies</i>	
tests/unit	<i>equivalent to library</i>	
tests/integration	UNIX-like	Depends on library injection (see <sup>2</sup> )

### 3.3 Requirements

The following is a list of software required to build Knot DNS Resolver from sources.

<sup>1</sup> Known to be running (not exclusively) on FreeBSD, Linux and OS X.

<sup>2</sup> Requires C99, `__attribute__((cleanup))` and `-MMD -MP` for dependency file generation. GCC, Clang and ICC are supported.

Requirement	Required by	Notes
GNU Make 3.80+	<i>all</i>	<i>(build only)</i>
C compiler	<i>all</i>	<i>(build only)</i> <sup>2</sup>
pkg-config	<i>all</i>	<i>(build only)</i> <sup>3</sup>
hexdump or xxd	daemon	<i>(build only)</i>
libknot 2.4.0+	<i>all</i>	Knot DNS library (requires autotools, GnuTLS and Jansson).
LuaJIT 2.0+	daemon	Embedded scripting language.
libuv 1.7+	daemon	Multiplatform I/O and services (libuv 1.0 with limitations <sup>4</sup> ).

There are also *optional* packages that enable specific functionality in Knot DNS Resolver, they are useful mainly for developers to build documentation and tests.

Optional	Needed for	Notes
lua-http	modules/http	HTTP/2 client/server for Lua.
luasocket	trust anchors, modules/ stats	Sockets for Lua.
luasec	trust anchors	TLS for Lua.
libmemcached	modules/memcached	To build memcached backend module.
hiredis	modules/redis	To build redis backend module.
Go 1.5+	modules	Build modules written in Go.
cmocka	unit tests	Unit testing framework.
Doxygen	documentation	Generating API documentation.
Sphinx sphinx_rtd_theme	documentation	Building this HTML/PDF documenta- tion.
breathe	documentation	Exposing Doxygen API doc to Sphinx.
libsystemd	daemon	Systemd socket activation support.
libprotobuf 3.0+	modules/dnstap	Protocol Buffers support for dnstap.
libprotobuf-c 1.0+	modules/dnstap	C bindings for Protobuf.
libfstrm 0.2+	modules/dnstap	Frame Streams data transport protocol.
luacheck	lint-lua	Syntax and static analysis checker for Lua.
clang-tidy	lint-c	Syntax and static analysis checker for C.
luacov	check-config	Code coverage analysis for Lua mod- ules.

### 3.3.1 Packaged dependencies

Most of the dependencies can be resolved from packages, here's an overview for several platforms.

- **Debian** (since *sid*) - current stable doesn't have libknot and libuv, which must be installed from sources.

```
sudo apt-get install pkg-config libknot-dev libuv1-dev libcmocka-dev liblua5.1-dev
```

- **Ubuntu** - unknown.
- **Fedora**

<sup>3</sup> You can use variables `<dependency>_CFLAGS` and `<dependency>_LIBS` to configure dependencies manually (i.e. `libknot_CFLAGS` and `libknot_LIBS`).

<sup>4</sup> libuv 1.7 brings `SO_REUSEPORT` support that is needed for multiple forks. libuv < 1.7 can be still used, but only in single-process mode. Use *different method* for load balancing.

```
# minimal build
sudo dnf install @buildsys-build knot-devel libuv-devel luajit-devel
# unit tests
sudo dnf install libcmocka-devel
# integration tests
sudo dnf install cmake git python-dns python-jinja2
# optional features
sudo dnf install golang hiredis-devel libmemcached-devel lua-sec-compat lua-socket-
↳compat systemd-devel
# docs
sudo dnf install doxygen python-breathe python-sphinx
```

- **RHEL/CentOS** - unknown.
- **openSUSE** - there is an [experimental package](#).
- **FreeBSD** - when installing from ports, all dependencies will install automatically, corresponding to the selected options.
- **NetBSD** - unknown.
- **OpenBSD** - unknown.
- **Mac OS X** - the dependencies can be found through [Homebrew](#).

```
brew install pkg-config libuv luajit cmocka
```

## 3.4 Building from sources

Initialize git submodules first.

```
$ git submodule update --init --recursive
```

The Knot DNS Resolver depends on the the Knot DNS library, recent version of libuv, and LuaJIT.

```
$ make info # See what's missing
```

When you have all the dependencies ready, you can build and install.

```
$ make PREFIX="/usr/local"
$ make install PREFIX="/usr/local"
```

---

**Note:** Always build with PREFIX if you want to install, as it is hardcoded in the executable for module search path. Production code should be compiled with `-DNDEBUG`. If you build the binary with `-DNOVERBOSELOG`, it won't be possible to turn on verbose logging; we advise packagers against using that flag.

---



---

**Note:** If you build with PREFIX, you may need to also set the LDFLAGS for the libraries:

---

```
make LDFLAGS="-Wl,-rpath=/usr/local/lib" PREFIX="/usr/local"
```

Alternatively you can build only specific parts of the project, i.e. library.

```
$ make lib
$ make lib-install
```

**Note:** Documentation is not built by default, run `make doc` to build it.

---

### 3.4.1 Building with security compiler flags

Knot DNS Resolver enables certain [security compile-time flags](#) that do not affect performance. You can add more flags to the build by appending them to `CFLAGS` variable, e.g. `make CFLAGS="-fstack-protector"`.

Method	Status	Notes
<code>-fstack-protector</code>	<i>dis-abled</i>	(must be specifically enabled in <code>CFLAGS</code> )
<code>-D_FORTIFY_SOURCE=2</code>	<b>en-abled</b>	
<code>-pie</code>	<b>en-abled</b>	enables ASLR for <code>kresd</code> (disable with <code>make HARDENING=no</code> )
<code>RELRO</code>	<b>en-abled</b>	full <sup>5</sup>

You can also disable linker hardening when it's unsupported with `make HARDENING=no`.

### 3.4.2 Building for packages

The build system supports `DESTDIR`

```
$ make install DESTDIR=/tmp/stage
```

**Tip:** There is a template for service file and AppArmor profile to help you kickstart the package.

---

### 3.4.3 Default paths

The default installation follows FHS with several custom paths for configuration and modules. All paths are prefixed with `PREFIX` variable by default if not specified otherwise.

---

<sup>5</sup> See `checksec.sh`



Component	Variable	Default	Notes
library	LIBDIR	\$(PREFIX)/lib	pkg-config is auto-generated <sup>6</sup>
daemon	SBINDIR	\$(PREFIX)/sbin	
configuration	ETCDIR	\$(PREFIX)/etc/ knot-resolver	Configuration file, templates.
modules	MODULEDIR	\$(LIBDIR) / kdns_modules	Runtime directory for loading dynamic modules <sup>7</sup> .
trust anchor file	KEYFILE_DEFAULT		Path to read-only trust anchor file, which is used as fallback when no other file is specified. <sup>8</sup>
work directory		the current directory	Run directory for daemon. (Only relevant during run time, not e.g. during installation.)

**Note:** Each module is self-contained and may install additional bundled files within \$(MODULEDIR) / \$(modulename). These files should be read-only, non-executable.

### 3.4.4 Static or dynamic?

By default the resolver library is built as a dynamic library with versioned ABI. You can revert to static build with `BUILDMODE` variable.

```
$ make BUILDMODE=dynamic # Default, create dynamic library
$ make BUILDMODE=static # Create static library
```

When the library is linked statically, it usually produces a smaller binary. However linking it to various C modules might violate ODR and increase the size.

### 3.4.5 Resolving dependencies

The build system relies on `pkg-config` to find dependencies. You can override it to force custom versions of the software by environment variables.

```
$ make libknot_CFLAGS="-I/opt/include" libknot_LIBS="-L/opt/lib -lknot -ldnssec"
```

Optional dependencies may be disabled as well using `HAS_x=yes|no` variable.

```
$ make HAS_go=no HAS_cmocka=no
```

**Warning:** If the dependencies lie outside of library search path, you need to add them somehow. Try `LD_LIBRARY_PATH` on Linux/BSD, and `DYLD_FALLBACK_LIBRARY_PATH` on OS X. Otherwise you need to add the locations to linker search path.

<sup>6</sup> The `libkres.pc` is installed in `$(LIBDIR)/pkgconfig`.

<sup>7</sup> The default `moduledir` can be changed with `-m` option to `kresd` daemon or by calling `moduledir()` function from lua.

<sup>8</sup> If no other trust anchor is specified by user, the compiled-in path `KEYFILE_DEFAULT` must contain a valid trust anchor. This is typically used by distributions which provide DNSSEC root trust anchors as part of distribution package. Users can disable the built-in trust anchor by adding `trust_anchors.keyfile_default = nil` to their configuration.

Several dependencies may not be in the packages yet, the script pulls and installs all dependencies in a chroot. You can avoid rebuilding dependencies by specifying `BUILD_IGNORE` variable, see the [Dockerfile](#) for example. Usually you only really need to rebuild `libknot`.

```
$ export FAKEROOT="${HOME}/.local"
$ export PKG_CONFIG_PATH="${FAKEROOT}/lib/pkgconfig"
$ export BUILD_IGNORE="..." # Ignore installed dependencies
$ ./scripts/bootstrap-depends.sh ${FAKEROOT}
```

### 3.4.6 Building extras

The project can be built with code coverage tracking using the `COVERAGE=1` variable.

The `make coverage` target gathers both `gcov` code coverage for C files, and `luacov` code coverage for Lua files and merges it for analysis. It requires `lcov` to be installed.

```
$ make coverage
```

### 3.4.7 Running unit and integration tests

The linter requires `luacheck` and `clang-tidy` and is executed by `make lint`. The unit tests require `cmocka` and are executed by `make check`. Tests for the `dnstap` module need `go` and are executed by `make check-dnstap`.

The integration tests use Deckard, the [DNS test harness](#).

```
$ make check-integration
```

Note that the daemon and modules must be installed first before running integration tests, the reason is that the daemon is otherwise unable to find and load modules.

Read the [documentation](#) for more information about requirements, how to run it and extend it.

## 3.5 Getting Docker image

Docker images require only either Linux or a Linux VM (see [boot2docker](#) on OS X).

```
$ docker run cznic/knot-resolver
```

See the [Docker images](#) page for more information and options. You can hack on the container by changing the container entrypoint to shell like:

```
$ docker run -it --entrypoint=/bin/bash cznic/knot-resolver
```

---

**Tip:** You can build the Docker image yourself with `docker build -t knot-resolver scripts`.

---

## 4.1 Requirements

- `libknot 2.0` (Knot DNS high-performance DNS library.)

## 4.2 For users

The library as described provides basic services for name resolution, which should cover the usage, examples are in the *resolve API* documentation.

---

**Tip:** If you're migrating from `getaddrinfo()`, see “*synchronous*” API, but the library offers iterative API as well to plug it into your event loop for example.

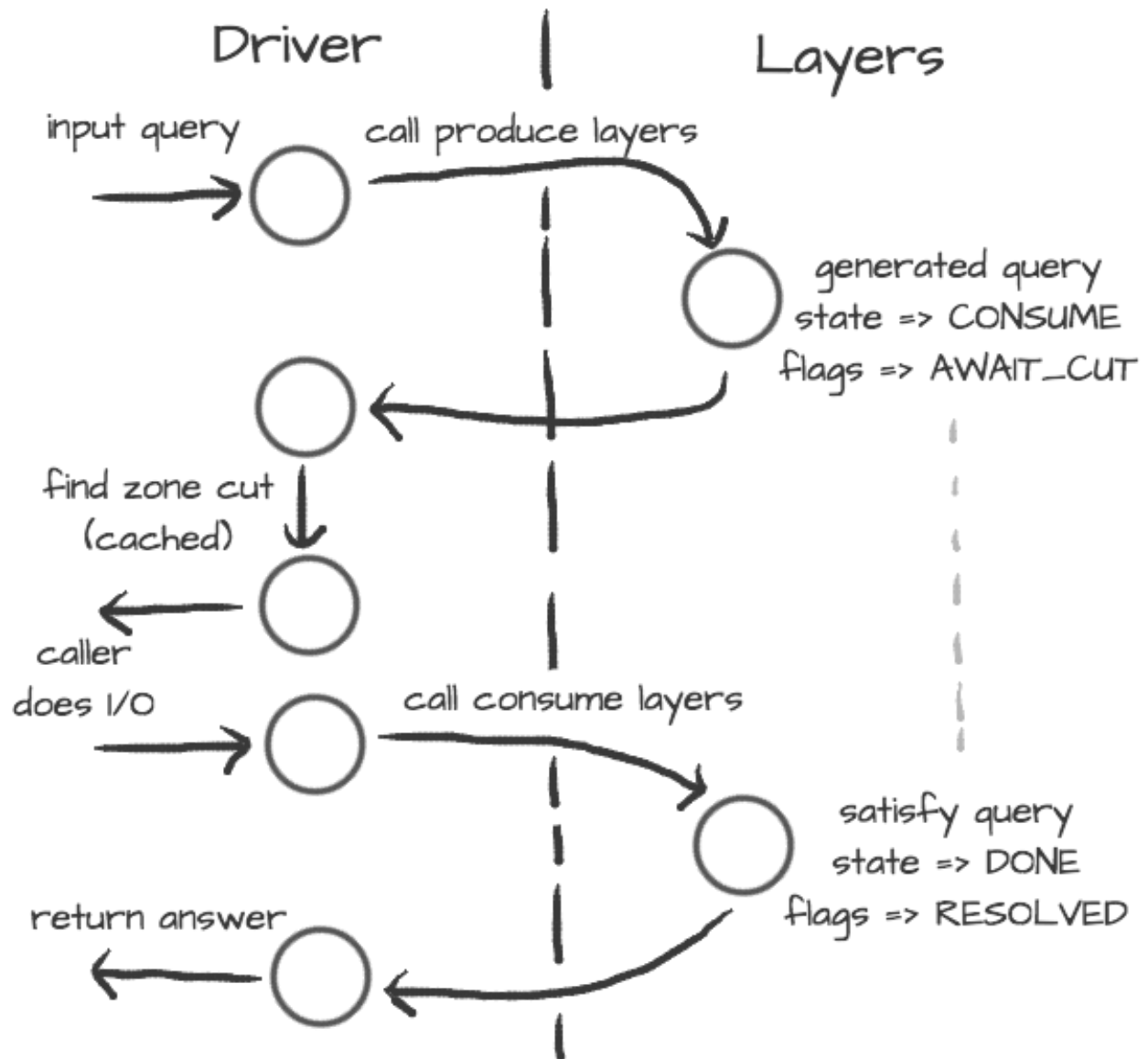
---

## 4.3 For developers

The resolution process starts with the functions in *resolve.c*, they are responsible for:

- reacting to state machine state (i.e. calling consume layers if we have an answer ready)
- interacting with the library user (i.e. asking caller for I/O, accepting queries)
- fetching assets needed by layers (i.e. zone cut)

This is the *driver*. The driver is not meant to know “*how*” the query resolves, but rather “*when*” to execute “*what*”.



On the other side are *layers*. They are responsible for dissecting the packets and informing the driver about the results. For example, a *produce* layer generates query, a *consume* layer validates answer.

**Tip:** Layers are executed asynchronously by the driver. If you need some asset beforehand, you can signalize the driver using returning state or current query flags. For example, setting a flag `AWAIT_CUT` forces driver to fetch zone cut information before the packet is consumed; setting a `RESOLVED` flag makes it pop a query after the current set of layers is finished; returning `FAIL` state makes it fail current query.

Layers can also change course of resolution, for example by appending additional queries.

```
consume = function (state, req, answer)
  answer = kres.pkt_t(answer)
  if answer:qtype() == kres.type.NS then
```

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```

        req = kres.request_t(req)
        local qry = req:push(answer:qname(), kres.type.SOA, kres.class.IN)
        qry.flags.AWAIT_CUT = true
    end
    return state
end

```

This **doesn't** block currently processed query, and the newly created sub-request will start as soon as driver finishes processing current. In some cases you might need to issue sub-request and process it **before** continuing with the current, i.e. validator may need a DNSKEY before it can validate signatures. In this case, layers can yield and resume afterwards.

```

consume = function (state, req, answer)
    answer = kres.pkt_t(answer)
    if state == kres.YIELD then
        print('continuing yielded layer')
        return kres.DONE
    else
        if answer:qtype() == kres.type.NS then
            req = kres.request_t(req)
            local qry = req:push(answer:qname(), kres.type.SOA, kres.
↪class.IN)

            qry.flags.AWAIT_CUT = true
            print('planned SOA query, yielding')
            return kres.YIELD
        end
        return state
    end
end
end

```

The YIELD state is a bit special. When a layer returns it, it interrupts current walk through the layers. When the layer receives it, it means that it yielded before and now it is resumed. This is useful in a situation where you need a sub-request to determine whether current answer is valid or not.

## 4.4 Writing layers

**Warning:** FIXME: this dev-docs section is outdated! Better see comments in files instead, for now.

The resolver *library* leverages the processing API from the libknot to separate packet processing code into layers.

**Note:** This is only crash-course in the library internals, see the resolver *library* documentation for the complete overview of the services.

The library offers following services:

- *Cache* - MVCC cache interface for retrieving/storing resource records.
- *Resolution plan* - Query resolution plan, a list of partial queries (with hierarchy) sent in order to satisfy original query. This contains information about the queries, nameserver choice, timing information, answer and its class.
- *Nameservers* - Reputation database of nameservers, this serves as an aid for nameserver choice.

A processing layer is going to be called by the query resolution driver for each query, so you're going to work with `struct kr_request` as your per-query context. This structure contains pointers to resolution context, resolution plan and also the final answer.

```
int consume(kr_layer_t *ctx, knot_pkt_t *pkt)
{
    struct kr_request *req = ctx->req;
    struct kr_query *qry = req->current_query;
}
```

This is only passive processing of the incoming answer. If you want to change the course of resolution, say satisfy a query from a local cache before the library issues a query to the nameserver, you can use states (see the *Static hints* for example).

```
int produce(kr_layer_t *ctx, knot_pkt_t *pkt)
{
    struct kr_request *req = ctx->req;
    struct kr_query *qry = req->current_query;

    /* Query can be satisfied locally. */
    if (can_satisfy(qry)) {
        /* This flag makes the resolver move the query
         * to the "resolved" list. */
        qry->flags.RESOLVED = true;
        return KR_STATE_DONE;
    }

    /* Pass-through. */
    return ctx->state;
}
```

It is possible to not only act during the query resolution, but also to view the complete resolution plan afterwards. This is useful for analysis-type tasks, or “*per answer*” hooks.

```
int finish(kr_layer_t *ctx)
{
    struct kr_request *req = ctx->req;
    struct kr_rplan *rplan = req->rplan;

    /* Print the query sequence with start time. */
    char qname_str[KNOT_DNAME_MAXLEN];
    struct kr_query *qry = NULL
    WALK_LIST(qry, rplan->resolved) {
        knot_dname_to_str(qname_str, qry->sname, sizeof(qname_str));
        printf("%s at %u\n", qname_str, qry->timestamp);
    }

    return ctx->state;
}
```

## 4.5 APIs in Lua

The APIs in Lua world try to mirror the C APIs using LuaJIT FFI, with several differences and enhancements. There is not comprehensive guide on the API yet, but you can have a look at the [bindings](#) file.

### 4.5.1 Elementary types and constants

- States are directly in `kres` table, e.g. `kres.YIELD`, `kres.CONSUME`, `kres.PRODUCE`, `kres.DONE`, `kres.FAIL`.
- DNS classes are in `kres.class` table, e.g. `kres.class.IN` for Internet class.
- DNS types are in `kres.type` table, e.g. `kres.type.AAAA` for AAAA type.
- DNS rcodes types are in `kres.rcode` table, e.g. `kres.rcode.NOERROR`.
- Packet sections (QUESTION, ANSWER, AUTHORITY, ADDITIONAL) are in the `kres.section` table.

### 4.5.2 Working with domain names

The internal API usually works with domain names in label format, you can convert between text and wire freely.

```
local dname = kres.str2dname('business.se')
local strname = kres.dname2str(dname)
```

### 4.5.3 Working with resource records

Resource records are stored as tables.

```
local rr = { owner = kres.str2dname('owner'),
            ttl = 0,
            class = kres.class.IN,
            type = kres.type.CNAME,
            rdata = kres.str2dname('someplace') }
print(kres.rr2str(rr))
```

RRSets in packet can be accessed using FFI, you can easily fetch single records.

```
local rrset = { ... }
local rr = rrset:get(0) -- Return first RR
print(kres.dname2str(rr:owner()))
print(rr:ttl())
print(kres.rr2str(rr))
```

### 4.5.4 Working with packets

Packet is the data structure that you're going to see in layers very often. They consists of a header, and four sections: QUESTION, ANSWER, AUTHORITY, ADDITIONAL. The first section is special, as it contains the query name, type, and class; the rest of the sections contain RRsets.

First you need to convert it to a type known to FFI and check basic properties. Let's start with a snippet of a *consume* layer.

```
consume = function (state, req, pkt)
    pkt = kres.pkt_t(answer)
    print('rcode:', pkt:rcode())
    print('query:', kres.dname2str(pkt:qname()), pkt:qclass(), pkt:qtype())
    if pkt:rcode() ~= kres.rcode.NOERROR then
        print('error response')
```

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```

    end
end

```

You can enumerate records in the sections.

```

local records = pkt:section(kres.section.ANSWER)
for i = 1, #records do
    local rr = records[i]
    if rr.type == kres.type.AAAA then
        print(kres.rr2str(rr))
    end
end
end

```

During *produce* or *begin*, you might want to write to packet. Keep in mind that you have to write packet sections in sequence, e.g. you can't write to ANSWER after writing AUTHORITY, it's like stages where you can't go back.

```

pkt:rcode(kres.rcode.NXDOMAIN)
-- Clear answer and write QUESTION
pkt:recycle()
pkt:question('\7blocked', kres.class.IN, kres.type.SOA)
-- Start writing data
pkt:begin(kres.section.ANSWER)
-- Nothing in answer
pkt:begin(kres.section.AUTHORITY)
local soa = { owner = '\7blocked', ttl = 900, class = kres.class.IN, type = kres.type.
↳SOA, rdata = '...' }
pkt:put(soa.owner, soa.ttl, soa.class, soa.type, soa.rdata)

```

### 4.5.5 Working with requests

The request holds information about currently processed query, enabled options, cache, and other extra data. You primarily need to retrieve currently processed query.

```

consume = function (state, req, pkt)
    req = kres.request_t(req)
    print(req.options)
    print(req.state)

    -- Print information about current query
    local current = req:current()
    print(kres.dname2str(current.owner))
    print(current.type, current.sclass, current.id, current.flags)
end

```

In layers that either begin or finalize, you can walk the list of resolved queries.

```

local last = req:resolved()
print(last.stype)

```

As described in the layers, you can not only retrieve information about current query, but also push new ones or pop old ones.



```

-- Push new query
local qry = req:push(pkt:qname(), kres.type.SOA, kres.class.IN)
qry.flags.AWAIT_CUT = true

-- Pop the query, this will erase it from resolution plan
req:pop(qry)

```

## 4.6 API reference

- *Name resolution*
- *Cache*
- *Nameservers*
- *Modules*
- *Utilities*
- *Generics library*

### 4.6.1 Name resolution

The API provides an API providing a “consumer-producer”-like interface to enable user to plug it into existing event loop or I/O code.

*Example usage of the iterative API:*

```

// Create request and its memory pool
struct kr_request req = {
    .pool = {
        .ctx = mp_new (4096),
        .alloc = (mm_alloc_t) mp_alloc
    }
};

// Setup and provide input query
int state = kr_resolve_begin(&req, ctx, final_answer);
state = kr_resolve_consume(&req, query);

// Generate answer
while (state == KR_STATE_PRODUCE) {

    // Additional query generate, do the I/O and pass back answer
    state = kr_resolve_produce(&req, &addr, &type, query);
    while (state == KR_STATE_CONSUME) {
        int ret = sendrecv(addr, proto, query, resp);

        // If I/O fails, make "resp" empty
        state = kr_resolve_consume(&request, addr, resp);
        knot_pkt_clear(resp);
    }
    knot_pkt_clear(query);
}

```

(continues on next page)

```
}  
  
// "state" is either DONE or FAIL  
kr_resolve_finish(&request, state);
```

## Defines

**kr\_request\_selected**(req)  
Initializer for an array of \*\_selected.

## Enums

### enum kr\_rank

RRset rank - for cache and ranked\_rr\_\*.

The rank meaning consists of one independent flag - KR\_RANK\_AUTH, and the rest have meaning of values where only one can hold at any time. You can use one of the enums as a safe initial value, optionally KR\_RANK\_AUTH; otherwise it's best to manipulate ranks via the kr\_rank\_\* functions.

See also: <https://tools.ietf.org/html/rfc2181#section-5.4.1> <https://tools.ietf.org/html/rfc4035#section-4.3>

**Note** The representation is complicated by restrictions on integer comparison:

- AUTH must be > than !AUTH
- AUTH INSECURE must be > than AUTH (because it attempted validation)
- !AUTH SECURE must be > than AUTH (because it's valid)

*Values:*

**KR\_RANK\_INITIAL** = 0

Did not attempt to validate.

It's assumed compulsory to validate (or prove insecure).

**KR\_RANK\_OMIT**

Do not attempt to validate.

(And don't consider it a validation failure.)

**KR\_RANK\_TRY**

Attempt to validate, but failures are non-fatal.

**KR\_RANK\_INDET** = 4

Unable to determine whether it should be secure.

**KR\_RANK\_BOGUS**

Ought to be secure but isn't.

**KR\_RANK\_MISMATCH**

**KR\_RANK\_MISSING**

Unable to obtain a good signature.

**KR\_RANK\_INSECURE** = 8

Proven to be insecure, i.e.

we have a chain of trust from TAs that cryptographically denies the possibility of existence of a positive chain of trust from the TAs to the record.

**KR\_RANK\_AUTH** = 16

Authoritative data flag; the chain of authority was “verified”.

Even if not set, only in-bailiwick stuff is acceptable, i.e. almost authoritative (example: mandatory glue and its NS RR).

**KR\_RANK\_SECURE** = 32

Verified whole chain of trust from the closest TA.

## Functions

bool **kr\_rank\_check** (uint8\_t *rank*)

Check that a rank value is valid.

Meant for assertions.

static bool **kr\_rank\_test** (uint8\_t *rank*, uint8\_t *kr\_flag*)

Test the presence of any flag/state in a rank, i.e.

including KR\_RANK\_AUTH.

static void **kr\_rank\_set** (uint8\_t \* *rank*, uint8\_t *kr\_flag*)

Set the rank state.

The \_AUTH flag is kept as it was.

*KR\_EXPORT* int **kr\_resolve\_begin** (struct *kr\_request* \* *request*, struct *kr\_context* \* *ctx*, knot\_pkt\_t \* *answer*)

Begin name resolution.

**Note** Expects a request to have an initialized mempool, the “answer” packet will be kept during the resolution and will contain the final answer at the end.

**Return** CONSUME (expecting query)

### Parameters

- *request*: request state with initialized mempool
- *ctx*: resolution context
- *answer*: allocated packet for final answer

*KR\_EXPORT* int **kr\_resolve\_consume** (struct *kr\_request* \* *request*, const struct sockaddr \* *src*, knot\_pkt\_t \* *packet*)

Consume input packet (may be either first query or answer to query originated from *kr\_resolve\_produce()*)

**Note** If the I/O fails, provide an empty or NULL packet, this will make iterator recognize nameserver failure.

**Return** any state

### Parameters

- *request*: request state (awaiting input)
- *src*: [in] packet source address
- *packet*: [in] input packet

*KR\_EXPORT* int **kr\_resolve\_produce** (struct *kr\_request* \* *request*, struct sockaddr \*\* *dst*, int \* *type*, knot\_pkt\_t \* *packet*)

Produce either next additional query or finish.

If the CONSUME is returned then `dst`, `type` and `packet` will be filled with appropriate values and caller is responsible to send them and receive answer. If it returns any other state, then content of the variables is undefined.

**Return** any state

### Parameters

- `request`: request state (in PRODUCE state)
- `dst`: [out] possible address of the next nameserver
- `type`: [out] possible used socket type (SOCK\_STREAM, SOCK\_DGRAM)
- `packet`: [out] packet to be filled with additional query

*KR\_EXPORT* int **kr\_resolve\_checkout** (struct *kr\_request* \* *request*, struct sockaddr \* *src*, struct sockaddr \* *dst*, int *type*, knot\_pkt\_t \* *packet*)

Finalises the outbound query packet with the knowledge of the IP addresses.

**Note** The function must be called before actual sending of the request packet.

**Return** `kr_ok()` or error code

### Parameters

- `request`: request state (in PRODUCE state)
- `src`: address from which the query is going to be sent
- `dst`: address of the name server
- `type`: used socket type (SOCK\_STREAM, SOCK\_DGRAM)
- `packet`: [in,out] query packet to be finalised

*KR\_EXPORT* int **kr\_resolve\_finish** (struct *kr\_request* \* *request*, int *state*)

Finish resolution and commit results if the state is DONE.

**Note** The structures will be deinitialized, but the assigned memory pool is not going to be destroyed, as it's owned by caller.

**Return** DONE

### Parameters

- `request`: request state
- `state`: either DONE or FAIL state

*KR\_EXPORT KR\_PURE* struct *kr\_rplan*\* **kr\_resolve\_plan** (struct *kr\_request* \* *request*)

Return resolution plan.

**Return** pointer to `rplan`

### Parameters

- `request`: request state

*KR\_EXPORT KR\_PURE* knot\_mm\_t\* **kr\_resolve\_pool** (struct *kr\_request* \* *request*)

Return memory pool associated with request.

**Return** mempool

## Parameters

- `request`: request state

### **struct `kr_context`**

*#include <resolve.h>* Name resolution context.

Resolution context provides basic services like cache, configuration and options.

**Note** This structure is persistent between name resolutions and may be shared between threads.

## Public Members

struct *kr\_qflags* **options**

knot\_rrset\_t\* **opt\_rr**

map\_t **trust\_anchors**

map\_t **negative\_anchors**

struct *kr\_zonecut* **root\_hints**

struct *kr\_cache* **cache**

kr\_nsrep\_rtt\_lru\_t\* **cache\_rtt**

unsigned **cache\_rtt\_tout\_retry\_interval**

kr\_nsrep\_lru\_t\* **cache\_rep**

module\_array\_t\* **modules**

struct *kr\_cookie\_ctx* **cookie\_ctx**

kr\_cookie\_lru\_t\* **cache\_cookie**

int32\_t **tls\_padding**

See `net.tls_padding` in `../daemon/README.rst` -1 is “true” (default policy), 0 is “false” (no padding)

knot\_mm\_t\* **pool**

### **struct `kr_request`**

*#include <resolve.h>* Name resolution request.

Keeps information about current query processing between calls to processing APIs, i.e. current resolved query, resolution plan, ... Use this instead of the simple interface if you want to implement multiplexing or custom I/O.

**Note** All data for this request must be allocated from the given pool.

## Public Members

struct *kr\_context*\* **ctx**

knot\_pkt\_t\* **answer**

struct *kr\_query*\* **current\_query**

Current evaluated query.

const knot\_rrset\_t\* **key**

`const struct sockaddr* addr`  
Address that originated the request.  
Current upstream address.  
NULL for internal origin.

`const struct sockaddr* dst_addr`  
Address that accepted the request.  
NULL for internal origin.

`const knot_pkt_t* packet`

`const knot_rrset_t* opt`

`bool tcp`  
true if the request is on tcp; only meaningful if (dst\_addr)

`size_t size`  
query packet size

`struct kr_request::@5 qsource`

`unsigned rtt`  
Current upstream RTT.

`struct kr_request::@6 upstream`  
Upstream information, valid only in consume() phase.

`struct kr_qflags options`

`int state`

`ranked_rr_array_t answ_selected`

`ranked_rr_array_t auth_selected`

`ranked_rr_array_t add_selected`

`rr_array_t additional`

`bool answ_validated`  
internal to validator; beware of caching, etc.

`bool auth_validated`  
see `answ_validated` ^^ ; TODO

`struct kr_rplan rplan`

`int has_tls`

`trace_log_f trace_log`  
Logging tracepoint.

`trace_callback_f trace_finish`  
Request finish tracepoint.

`knot_mm_t pool`

### Typedefs

`typedef int32_t(* kr_stale_cb) (int32_t tll, const knot_dname_t *owner, uint16_t type, const struct kr_query *qry)`  
Callback for serve-stale decisions.

**Return** the adjusted TTL (typically 1) or < 0.

**Parameters**

- `t11`: the expired TTL (i.e. it's < 0)

## Functions

*KR\_EXPORT* void **kr\_qflags\_set** (struct *kr\_qflags* \* *f1*, struct *kr\_qflags* *f2*)  
Combine flags together.

This means set union for simple flags.

*KR\_EXPORT* void **kr\_qflags\_clear** (struct *kr\_qflags* \* *f1*, struct *kr\_qflags* *f2*)  
Remove flags.

This means set-theoretic difference.

*KR\_EXPORT* int **kr\_rplan\_init** (struct *kr\_rplan* \* *rplan*, struct *kr\_request* \* *request*, knot\_mm\_t \* *pool*)  
Initialize resolution plan (empty).

**Parameters**

- `rplan`: plan instance
- `request`: resolution request
- `pool`: ephemeral memory pool for whole resolution

*KR\_EXPORT* void **kr\_rplan\_deinit** (struct *kr\_rplan* \* *rplan*)  
Deinitialize resolution plan, aborting any uncommitted transactions.

**Parameters**

- `rplan`: plan instance

*KR\_EXPORT KR\_PURE* bool **kr\_rplan\_empty** (struct *kr\_rplan* \* *rplan*)  
Return true if the resolution plan is empty (i.e.

finished or initialized)

**Return** true or false

**Parameters**

- `rplan`: plan instance

*KR\_EXPORT* struct *kr\_query*\* **kr\_rplan\_push\_empty** (struct *kr\_rplan* \* *rplan*, struct *kr\_query* \* *parent*)  
Push empty query to the top of the resolution plan.

**Note** This query serves as a cookie query only.

**Return** query instance or NULL

**Parameters**

- `rplan`: plan instance
- `parent`: query parent (or NULL)

*KR\_EXPORT* struct *kr\_query*\* **kr\_rplan\_push** (struct *kr\_rplan* \* *rplan*, struct *kr\_query* \* *parent*, const  
knot\_dname\_t \* *name*, uint16\_t *cls*, uint16\_t *type*)  
Push a query to the top of the resolution plan.

**Note** This means that this query takes precedence before all pending queries.

**Return** query instance or NULL

**Parameters**

- `rplan`: plan instance
- `parent`: query parent (or NULL)
- `name`: resolved name
- `cls`: resolved class
- `type`: resolved type

*KR\_EXPORT* int **kr\_rplan\_pop** (struct *kr\_rplan* \* *rplan*, struct *kr\_query* \* *qry*)  
Pop existing query from the resolution plan.

**Note** Popped queries are not discarded, but moved to the resolved list.

**Return** 0 or an error

**Parameters**

- `rplan`: plan instance
- `qry`: resolved query

*KR\_EXPORT KR\_PURE* bool **kr\_rplan\_satisfies** (struct *kr\_query* \* *closure*, const knot\_dname\_t \* *name*, uint16\_t *cls*, uint16\_t *type*)  
Return true if resolution chain satisfies given query.

*KR\_EXPORT KR\_PURE* struct *kr\_query*\* **kr\_rplan\_resolved** (struct *kr\_rplan* \* *rplan*)  
Return last resolved query.

*KR\_EXPORT KR\_PURE* struct *kr\_query*\* **kr\_rplan\_last** (struct *kr\_rplan* \* *rplan*)  
Return last query (either currently being solved or last resolved).

This is necessary to retrieve the last query in case of resolution failures (e.g. time limit reached).

*KR\_EXPORT KR\_PURE* struct *kr\_query*\* **kr\_rplan\_find\_resolved** (struct *kr\_rplan* \* *rplan*, struct *kr\_query* \* *parent*, const knot\_dname\_t \* *name*, uint16\_t *cls*, uint16\_t *type*)

Check if a given query already resolved.

**Return** query instance or NULL

**Parameters**

- `rplan`: plan instance
- `parent`: query parent (or NULL)
- `name`: resolved name
- `cls`: resolved class
- `type`: resolved type

**struct kr\_qflags**  
*#include <rplan.h>* Query flags.



## Public Members

- bool **NO\_MINIMIZE**  
Don't minimize QNAME.
- bool **NO\_THROTTLE**  
No query/slow NS throttling.
- bool **NO\_IPV6**  
Disable IPv6.
- bool **NO\_IPV4**  
Disable IPv4.
- bool **TCP**  
Use TCP for this query.
- bool **RESOLVED**  
Query is resolved.
- bool **AWAIT\_IPV4**  
Query is waiting for A address.
- bool **AWAIT\_IPV6**  
Query is waiting for AAAA address.
- bool **AWAIT\_CUT**  
Query is waiting for zone cut lookup.
- bool **SAFEMODE**  
Don't use fancy stuff (EDNS, 0x20, ...)
- bool **CACHED**  
Query response is cached.
- bool **NO\_CACHE**  
No cache for lookup; exception: finding NSs and subqueries.
- bool **EXPIRING**  
Query response is cached, but expiring.
- bool **ALLOW\_LOCAL**  
Allow queries to local or private address ranges.
- bool **DNSSEC\_WANT**  
Want DNSSEC secured answer; exception: +cd, i.e.  
knot\_wire\_set\_cd(request->answer->wire).
- bool **DNSSEC\_BOGUS**  
Query response is DNSSEC bogus.
- bool **DNSSEC\_INSECURE**  
Query response is DNSSEC insecure.
- bool **DNSSEC\_CD**  
CD bit in query.
- bool **STUB**  
Stub resolution, accept received answer as solved.
- bool **ALWAYS\_CUT**  
Always recover zone cut (even if cached).

bool **DNSSEC\_WEXPAND**  
Query response has wildcard expansion.

bool **PERMISSIVE**  
Permissive resolver mode.

bool **STRICT**  
Strict resolver mode.

bool **BADCOOKIE\_AGAIN**  
Query again because bad cookie returned.

bool **CNAME**  
Query response contains CNAME in answer section.

bool **REORDER\_RR**  
Reorder cached RRs.

bool **TRACE**  
Also log answers if verbose.

bool **NO\_0X20**  
Disable query case randomization .

bool **DNSSEC\_NODS**  
DS non-existence is proven.

bool **DNSSEC\_OPTOUT**  
Closest encloser proof has optout.

bool **NONAUTH**  
Non-authoritative in-bailiwick records are enough.  
  
TODO: utilize this also outside cache.

bool **FORWARD**  
Forward all queries to upstream; validate answers.

bool **DNS64\_MARK**  
Internal mark for dns64 module.

bool **CACHE\_TRIED**  
Internal to cache module.

bool **NO\_NS\_FOUND**  
No valid NS found during last PRODUCE stage.

```
struct kr_query  
#include <rplan.h> Single query representation.
```

### Public Members

```
struct kr_query* parent  
knot_dname_t* sname  
The name to resolve - lower-cased, uncompressed.  
uint16_t stype  
uint16_t sclass  
uint16_t id
```

```

struct kr_qflags flags forward_flags
uint32_t secret
uint16_t fails
uint16_t reorder
    Seed to reorder (cached) RRs in answer or zero.
uint64_t creation_time_mono
uint64_t timestamp_mono
    Time of query created or time of query to upstream resolver (milliseconds).
struct timeval timestamp
    Real time for TTL+DNSSEC checks (.tv_sec only).
struct kr_zonecut zone_cut
struct kr_layer_pickle* deferred
uint32_t uid
    Query iteration number, unique within the kr_rplan.
struct kr_query* cname_parent
    Pointer to the query that originated this one because of following a CNAME (or NULL).
struct kr_request* request
    Parent resolution request.
kr_stale_cb stale_cb
    See the type.
struct kr_nsrep ns

```

**struct kr\_rplan**

*#include <rplan.h>* Query resolution plan structure.

The structure most importantly holds the original query, answer and the list of pending queries required to resolve the original query. It also keeps a notion of current zone cut.

**Public Members**

```

kr_qarray_t pending
    List of pending queries.
kr_qarray_t resolved
    List of resolved queries.
struct kr_request* request
    Parent resolution request.
knot_mm_t* pool
    Temporary memory pool.
uint32_t next_uid
    Next value for kr_query::uid (incremental).

```

## 4.6.2 Cache

### Functions

int **cache\_peek** (kr\_layer\_t \* *ctx*, knot\_pkt\_t \* *pkt*)

int **cache\_stash** (kr\_layer\_t \* *ctx*, knot\_pkt\_t \* *pkt*)

*KR\_EXPORT* int **kr\_cache\_open** (struct *kr\_cache* \* *cache*, const struct kr\_cdb\_api \* *api*, struct kr\_cdb\_opts \* *opts*, knot\_mm\_t \* *mm*)

Open/create cache with provided storage options.

**Return** 0 or an error code

#### Parameters

- *cache*: cache structure to be initialized
- *api*: storage engine API
- *opts*: storage-specific options (may be NULL for default)
- *mm*: memory context.

*KR\_EXPORT* void **kr\_cache\_close** (struct *kr\_cache* \* *cache*)

Close persistent cache.

**Note** This doesn't clear the data, just closes the connection to the database.

#### Parameters

- *cache*: structure

*KR\_EXPORT* int **kr\_cache\_sync** (struct *kr\_cache* \* *cache*)

Run after a row of operations to release transaction/lock if needed.

static bool **kr\_cache\_is\_open** (struct *kr\_cache* \* *cache*)

Return true if cache is open and enabled.

static void **kr\_cache\_make\_checkpoint** (struct *kr\_cache* \* *cache*)

(Re)set the time pair to the current values.

*KR\_EXPORT* int **kr\_cache\_clear** (struct *kr\_cache* \* *cache*)

Clear all items from the cache.

**Return** 0 or an errcode

#### Parameters

- *cache*: cache structure

*KR\_EXPORT* int **kr\_cache\_peek\_exact** (struct *kr\_cache* \* *cache*, const knot\_dname\_t \* *name*, uint16\_t *type*, struct *kr\_cache\_p* \* *peek*)

*KR\_EXPORT* int32\_t **kr\_cache\_ttl** (const struct *kr\_cache\_p* \* *peek*, const struct *kr\_query* \* *qry*, const knot\_dname\_t \* *name*, uint16\_t *type*)

*KR\_EXPORT* int **kr\_cache\_materialize** (knot\_rdataset\_t \* *dst*, const struct *kr\_cache\_p* \* *ref*, uint32\_t *new\_ttl*, knot\_mm\_t \* *pool*)

## Variables

const size\_t **PKT\_SIZE\_NOWIRE** = -1

When knot\_pkt is passed from cache without ->wire, this is the ->size.

**struct kr\_cache**

*#include <api.h>* Cache structure, keeps API, instance and metadata.

### Public Members

knot\_db\_t\* **db**

Storage instance.

const struct kr\_cdb\_api\* **api**

Storage engine.

uint32\_t **hit**

Number of cache hits.

uint32\_t **miss**

Number of cache misses.

uint32\_t **insert**

Number of insertions.

uint32\_t **delete**

Number of deletions.

struct *kr\_cache::*@0 **stats**

uint32\_t **t1\_min**

uint32\_t **t1\_max**

TTL limits.

struct timeval **checkpoint\_walltime**

Wall time on the last check-point.

uint64\_t **checkpoint\_monotime**

Monotonic milliseconds on the last check-point.

**struct kr\_cache\_p**

### Public Members

uint32\_t **time**

The time of inception.

uint32\_t **t1**

TTL at inception moment.

Assuming it fits into int32\_t ATM.

uint8\_t **rank**

See enum kr\_rank.

void\* **raw\_data**

void \* **raw\_bound**

struct *kr\_cache\_p::*@1 *kr\_cache\_p::*@2

### 4.6.3 Nameservers

#### Defines

**KR\_NS\_DEAD**

See `kr_nsrep_update_rtt()`

**KR\_NS\_TIMEOUT\_RETRY\_INTERVAL**

**KR\_NSREP\_MAXADDR**

#### Typedefs

**typedef** struct *kr\_nsrep\_rtt\_lru\_entry* **kr\_nsrep\_rtt\_lru\_entry\_t**

#### Enums

**enum kr\_ns\_score**

NS RTT score (special values).

**Note** RTT is measured in milliseconds.

*Values:*

**KR\_NS\_MAX\_SCORE** = KR\_CONN\_RTT\_MAX

**KR\_NS\_TIMEOUT** = (95 \* KR\_NS\_MAX\_SCORE) / 100

**KR\_NS\_LONG** = (3 \* KR\_NS\_TIMEOUT) / 4

**KR\_NS\_UNKNOWN** = KR\_NS\_TIMEOUT / 2

**KR\_NS\_PENALTY** = 100

**KR\_NS\_GLUED** = 10

**enum kr\_ns\_rep**

NS QoS flags.

*Values:*

**KR\_NS\_NOIP4** = 1 << 0

NS has no IPv4.

**KR\_NS\_NOIP6** = 1 << 1

NS has no IPv6.

**KR\_NS\_NOEDNS** = 1 << 2

NS has no EDNS support.

**enum kr\_ns\_update\_mode**

NS RTT update modes.

First update is always KR\_NS\_RESET unless KR\_NS\_UPDATE\_NORESET mode had choosen.

*Values:*

**KR\_NS\_UPDATE** = 0

Update as smooth over last two measurements.

**KR\_NS\_UPDATE\_NORESET**

Same as KR\_NS\_UPDATE, but disable fallback to KR\_NS\_RESET on newly added entries.

Zero is used as initial value.

**KR\_NS\_RESET**

Set to given value.

**KR\_NS\_ADD**

Increment current value.

**KR\_NS\_MAX**

Set to maximum of current/proposed value.

## Functions

typedef **lru\_t** (*kr\_nsrep\_rtt\_lru\_entry\_t*)

NS QoS tracking.

typedef **lru\_t** (unsigned)

NS reputation tracking.

**KR\_EXPORT** int **kr\_nsrep\_set** (struct *kr\_query* \* *qry*, size\_t *index*, const struct sockaddr \* *sock*)

Set given NS address.

**Return** 0 or an error code

### Parameters

- *qry*: updated query
- *index*: index of the updated target
- *sock*: socket address to use (sockaddr\_in or sockaddr\_in6 or NULL)

**KR\_EXPORT** int **kr\_nsrep\_select** (struct *kr\_query* \* *qry*, struct *kr\_context* \* *ctx*)

Select best nameserver/address pair from the nsset.

**Return** 0 or an error code

### Parameters

- *qry*: updated query
- *ctx*: resolution context

**KR\_EXPORT** int **kr\_nsrep\_select\_addr** (struct *kr\_query* \* *qry*, struct *kr\_context* \* *ctx*)

Select best nameserver/address pair from the nsset.

**Return** 0 or an error code

### Parameters

- *qry*: updated query
- *ctx*: resolution context

**KR\_EXPORT** int **kr\_nsrep\_update\_rtt** (struct *kr\_nsrep* \* *ns*, const struct sockaddr \* *addr*, unsigned *score*, kr\_nsrep\_rtt\_lru\_t \* *cache*, int *umode*)

Update NS address RTT information.

In KR\_NS\_UPDATE mode reputation is smoothed over last N measurements.

**Return** 0 on success, error code on failure

**Parameters**

- ns: updated NS representation
- addr: chosen address (NULL for first)
- score: new score (i.e. RTT), see enum `kr_ns_score` after two calls with `score = KR_NS_DEAD` and `umode = KR_NS_UPDATE` server will be guaranteed to have `KR_NS_TIMEOUTED` score
- cache: RTT LRU cache
- umode: update mode (`KR_NS_UPDATE` or `KR_NS_RESET` or `KR_NS_ADD`)

*KR\_EXPORT* int **kr\_nsrep\_update\_rep** (struct *kr\_nsrep* \* ns, unsigned *reputation*, *kr\_nsrep\_lru\_t* \* *cache*)

Update NSSET reputation information.

**Return** 0 on success, error code on failure

**Parameters**

- ns: updated NS representation
- reputation: combined reputation flags, see enum `kr_ns_rep`
- cache: LRU cache

int **kr\_nsrep\_copy\_set** (struct *kr\_nsrep* \* dst, const struct *kr\_nsrep* \* src)

Copy NSSET reputation information and resets score.

**Return** 0 on success, error code on failure

**Parameters**

- dst: updated NS representation
- src: source NS representation

*KR\_EXPORT* int **kr\_nsrep\_sort** (struct *kr\_nsrep* \* ns, *kr\_nsrep\_rtt\_lru\_t* \* *rtt\_cache*)

Sort addresses in the query nsrep list.

**Return** 0 or an error code

**Note** ns reputation is zeroed, as `KR_NS_NOIP{4,6}` flags are useless in STUB/FORWARD mode.

**Parameters**

- ns: updated *kr\_nsrep*
- rtt\_cache: RTT LRU cache

**struct kr\_nsrep\_rtt\_lru\_entry**

**Public Members**

unsigned **score**

uint64\_t **tout\_timestamp**



**struct kr\_nsrep**

*#include <nsrep.h>* Name server representation.

Contains extra information about the name server, e.g. score or other metadata.

**Public Members**

unsigned **score**

NS score.

unsigned **reputation**

NS reputation.

const knot\_dname\_t\* **name**

NS name.

struct *kr\_context*\* **ctx**

Resolution context.

**union inaddr kr\_nsrep::addr**[KR\_NSREP\_MAXADDR]

NS address(es)

**Functions**

*KR\_EXPORT* int **kr\_zonecut\_init** (struct *kr\_zonecut* \* *cut*, const knot\_dname\_t \* *name*, knot\_mm\_t \* *pool*)

Populate root zone cut with SBELT.

**Return** 0 or error code

**Parameters**

- *cut*: zone cut
- *name*:
- *pool*:

*KR\_EXPORT* void **kr\_zonecut\_deinit** (struct *kr\_zonecut* \* *cut*)

Clear the structure and free the address set.

**Parameters**

- *cut*: zone cut

*KR\_EXPORT* void **kr\_zonecut\_set** (struct *kr\_zonecut* \* *cut*, const knot\_dname\_t \* *name*)

Reset zone cut to given name and clear address list.

**Note** This clears the address list even if the name doesn't change. TA and DNSKEY don't change.

**Parameters**

- *cut*: zone cut to be set
- *name*: new zone cut name

*KR\_EXPORT* int **kr\_zonecut\_copy** (struct *kr\_zonecut* \* *dst*, const struct *kr\_zonecut* \* *src*)

Copy zone cut, including all data.

Does not copy keys and trust anchor.

**Return** 0 or an error code

**Parameters**

- *dst*: destination zone cut
- *src*: source zone cut

*KR\_EXPORT* int **kr\_zonecut\_copy\_trust** (struct *kr\_zonecut* \* *dst*, const struct *kr\_zonecut* \* *src*)

Copy zone trust anchor and keys.

**Return** 0 or an error code

**Parameters**

- *dst*: destination zone cut
- *src*: source zone cut

*KR\_EXPORT* int **kr\_zonecut\_add** (struct *kr\_zonecut* \* *cut*, const knot\_dname\_t \* *ns*, const knot\_rdata\_t \* *rdata*)

Add address record to the zone cut.

The record will be merged with existing data, it may be either A/AAAA type.

**Return** 0 or error code

**Parameters**

- *cut*: zone cut to be populated
- *ns*: nameserver name
- *rdata*: nameserver address (as rdata)

*KR\_EXPORT* int **kr\_zonecut\_del** (struct *kr\_zonecut* \* *cut*, const knot\_dname\_t \* *ns*, const knot\_rdata\_t \* *rdata*)

Delete nameserver/address pair from the zone cut.

**Return** 0 or error code

**Parameters**

- *cut*:
- *ns*: name server name
- *rdata*: name server address

*KR\_EXPORT* int **kr\_zonecut\_del\_all** (struct *kr\_zonecut* \* *cut*, const knot\_dname\_t \* *ns*)

Delete all addresses associated with the given name.

**Return** 0 or error code

**Parameters**

- *cut*:
- *ns*: name server name

*KR\_EXPORT KR\_PURE* `pack_t* kr_zonecut_find (struct kr_zonecut * cut, const knot_dname_t * ns)`  
Find nameserver address list in the zone cut.

**Note** This can be used for membership test, a non-null pack is returned if the nameserver name exists.

**Return** pack of addresses or NULL

**Parameters**

- *cut*:
- *ns*: name server name

*KR\_EXPORT* `int kr_zonecut_set_sbelt (struct kr_context * ctx, struct kr_zonecut * cut)`  
Populate zone cut with a root zone using SBELT :rfc:1034

**Return** 0 or error code

**Parameters**

- *ctx*: resolution context (to fetch root hints)
- *cut*: zone cut to be populated

*KR\_EXPORT* `int kr_zonecut_find_cached (struct kr_context * ctx, struct kr_zonecut * cut, const knot_dname_t * name, const struct kr_query * qry, bool *restrict secured)`

Populate zone cut address set from cache.

**Return** 0 or error code (ENOENT if it doesn't find anything)

**Parameters**

- *ctx*: resolution context (to fetch data from LRU caches)
- *cut*: zone cut to be populated
- *name*: QNAME to start finding zone cut for
- *qry*: query for timestamp and stale-serving decisions
- *secured*: set to true if want secured zone cut, will return false if it is provably insecure

**struct *kr\_zonecut***  
*#include* <*zonecut.h*> Current zone cut representation.

**Public Members**

`knot_dname_t* name`  
Zone cut name.

`knot_rrset_t* key`  
Zone cut DNSKEY.

`knot_rrset_t* trust_anchor`  
Current trust anchor.

`struct kr_zonecut* parent`  
Parent zone cut.

`map_t nsset`  
Map of nameserver => address\_set.

knot\_mm\_t\* **pool**  
Memory pool.

### 4.6.4 Modules

Module API definition and functions for (un)loading modules.

#### Defines

**KR\_MODULE\_EXPORT** (module)  
Export module API version (place this at the end of your module).

#### Parameters

- `module`: module name (f.e. hints)

#### **KR\_MODULE\_API**

#### Typedefs

**typedef** uint32\_t ( **module\_api\_cb**) (void)

**typedef** char\* ( **kr\_prop\_cb**) (void \**env*, struct *kr\_module* \**self*, const char \**input*)  
Module property callback.

Input and output is passed via a JSON encoded in a string.

**Return** a free-form JSON output (malloc-ated)

#### Parameters

- `env`: pointer to the lua engine, i.e. struct engine \**env* (TODO: explicit type)
- `input`: parameter (NULL if missing/nil on lua level)

#### Functions

**KR\_EXPORT** int **kr\_module\_load** (struct *kr\_module* \* *module*, const char \* *name*, const char \* *path*)  
Load a C module instance into memory.

**Return** 0 or an error

#### Parameters

- `module`: module structure
- `name`: module name
- `path`: module search path

**KR\_EXPORT** void **kr\_module\_unload** (struct *kr\_module* \* *module*)  
Unload module instance.

#### Parameters

- `module`: module structure

*KR\_EXPORT* const struct *kr\_module*\* **kr\_module\_embedded** (const char \* *name*)

Get embedded module prototype by name (or NULL).

**struct kr\_module**

*#include <module.h>* Module representation.

The five symbols (*init*, ...) may be defined by the module as *name\_init*(), etc; all are optional and missing symbols are represented as NULLs;

## Public Members

char\* **name**

**intinit**) (struct *kr\_module* \**self*)

Constructor.

Called after loading the module.

**Return** error code.

**intdeinit**) (struct *kr\_module* \**self*)

Destructor.

Called before unloading the module.

**Return** error code.

**intconfig**) (struct *kr\_module* \**self*, const char \**input*)

Configure with encoded JSON (NULL if missing).

**Return** error code.

const *kr\_layer\_api\_t*\* **layer**) (struct *kr\_module* \**self*)

Get a pointer to packet processing API specs.

See docs on that type.

const struct *kr\_prop*\* **props**) (void)

Get a pointer to list of properties, terminated by { NULL, NULL, NULL }.

void\* **lib**

Shared library handle or RTLD\_DEFAULT.

void\* **data**

Custom data context.

**struct kr\_prop**

*#include <module.h>* Module property (named callable).

## Public Members

*kr\_prop\_cb*\* **cb**

const char\* **name**

const char\* **info**

## 4.6.5 Utilities

### Defines

`kr_log_info` (*fmt*, ...)

`kr_log_error` (*fmt*, ...)

`kr_log_trace_enabled` (query)  
Return true if the query has request log handler installed.

`VERBOSE_STATUS`  
Block run in verbose mode; optimized when not run.

`WITH_VERBOSE` (query)

`kr_log_verbose`

`static_assert` (cond, msg)

`RDATA_ARR_MAX`

`kr_rdataset_next` (rd)

`KR_RRKEY_LEN`

`SWAP` (x, y)  
Swap two places.

Note: the parameters need to be without side effects.

### Typedefs

`typedef void (* trace_callback_f)` (struct *kr\_request* \*request)  
Callback for request events.

`typedef void (* trace_log_f)` (const struct *kr\_query* \*query, const char \*source, const char \*msg)  
Callback for request logging handler.

### Functions

`KR_EXPORT` bool `kr_verbose_set` (bool status)  
Set verbose mode.  
Not available if compiled with -DNOVERBOSELOG.

`KR_EXPORT` `KR_PRINTF` (1)  
Log a message if in verbose mode.

`KR_EXPORT` `KR_PRINTF` (3)  
Log a message through the request log handler.

**Return** true if the message was logged

#### Parameters

- query: current query
- source: message source
- fmt: message format

static long **time\_diff** (struct timeval \* *begin*, struct timeval \* *end*)  
Return time difference in milliseconds.

**Note** based on the `_BSD_SOURCE` `timersub()` macro

*KR\_EXPORT* char\* **kr\_strcatdup** (unsigned *n*, ...)  
Concatenate *N* strings.

int **kr\_rand\_reseed** (void)  
Reseed CSPRNG context.

*KR\_EXPORT* uint32\_t **kr\_rand\_uint** (uint32\_t *max*)  
Get pseudo-random value between zero and *max*-1 (inclusive).

Passing zero means that any `uint32_t` should be returned (it's also faster).

*KR\_EXPORT* int **kr\_memreserve** (void \* *baton*, char \*\* *mem*, size\_t *elm\_size*, size\_t *want*, size\_t \* *have*)  
Memory reservation routine for `knot_mm_t`.

*KR\_EXPORT* int **kr\_pkt\_recycle** (knot\_pkt\_t \* *pkt*)

*KR\_EXPORT* int **kr\_pkt\_clear\_payload** (knot\_pkt\_t \* *pkt*)

*KR\_EXPORT* int **kr\_pkt\_put** (knot\_pkt\_t \* *pkt*, const knot\_dname\_t \* *name*, uint32\_t *ttl*, uint16\_t *rclass*,  
uint16\_t *rtype*, const uint8\_t \* *rdata*, uint16\_t *rrlen*)  
Construct and put record to packet.

*KR\_EXPORT* void **kr\_pkt\_make\_auth\_header** (knot\_pkt\_t \* *pkt*)  
Set packet header suitable for authoritative answer.

(for policy module)

*KR\_EXPORT KR\_PURE* const char\* **kr\_inaddr** (const struct sockaddr \* *addr*)  
Address bytes for given family.

*KR\_EXPORT KR\_PURE* int **kr\_inaddr\_family** (const struct sockaddr \* *addr*)  
Address family.

*KR\_EXPORT KR\_PURE* int **kr\_inaddr\_len** (const struct sockaddr \* *addr*)  
Address length for given family, i.e.  
`sizeof(struct in*_addr)`.

*KR\_EXPORT KR\_PURE* int **kr\_sockaddr\_len** (const struct sockaddr \* *addr*)  
Sockaddr length for given family, i.e.  
`sizeof(struct sockaddr_in*)`.

*KR\_EXPORT KR\_PURE* uint16\_t **kr\_inaddr\_port** (const struct sockaddr \* *addr*)  
Port.

*KR\_EXPORT* int **kr\_inaddr\_str** (const struct sockaddr \* *addr*, char \* *buf*, size\_t \* *buflen*)  
String representation for given address as "`<addr>#<port>`".

*KR\_EXPORT KR\_PURE* int **kr\_straddr\_family** (const char \* *addr*)  
Return address type for string.

*KR\_EXPORT KR\_CONST* int **kr\_family\_len** (int *family*)  
Return address length in given family (`struct in*_addr`).

*KR\_EXPORT* struct sockaddr\* **kr\_straddr\_socket** (const char \* *addr*, int *port*)  
Create a `sockaddr*` from string+port representation (also accepts IPv6 link-local).

*KR\_EXPORT* int **kr\_straddr\_subnet** (void \* *dst*, const char \* *addr*)  
Parse address and return subnet length (bits).

**Warning** `'dst'` must be at least `sizeof(struct in6_addr)` long.

*KR\_EXPORT* `int kr_straddr_split (const char * addr, char * buf, size_t buflen, uint16_t * port)`  
Splits ip address specified as “addr@port” or “addr#port” into addr and port and performs validation.

**Note** if #port part isn't present, then port will be set to 0. buf and port can be set to NULL.

**Return** `kr_error(EINVAL)` - addr part doesn't contains valid ip address or #port part is out-of-range (either < 0 either > `UINT16_MAX`) `kr_error(ENOSP)` - buflen is too small

*KR\_EXPORT* `int kr_straddr_join (const char * addr, uint16_t port, char * buf, size_t * buflen)`  
Formats ip address and port in “addr#port” format.  
and performs validation.

**Note** Port always formatted as five-character string with leading zeros.

**Return** `kr_error(EINVAL)` - addr or buf is NULL or buflen is 0 or addr doesn't contain a valid ip address  
`kr_error(ENOSP)` - buflen is too small

*KR\_EXPORT KR\_PURE* `int kr_bitcmp (const char * a, const char * b, int bits)`  
Compare memory bitwise.

The semantics is “the same” as for `memcmp()`. The partial byte is considered with more-significant bits first, so this is e.g. suitable for comparing IP prefixes.

`static uint8_t KEY_FLAG_RANK (const char * key)`

`static bool KEY_COVERING_RRSIG (const char * key)`

*KR\_EXPORT* `int kr_rrkey (char * key, const knot_dname_t * owner, uint16_t type, uint8_t rank)`  
Create unique null-terminated string key for RR.

**Return** key length if successful or an error

### Parameters

- `key`: Destination buffer for key size, MUST be `KR_RRKEY_LEN` or larger.
- `owner`: RR owner domain name.
- `type`: RR type.
- `rank`: RR rank (8 bit tag usable for anything).

*KR\_EXPORT* `int kr_ranked_rrarray_add (ranked_rr_array_t * array, const knot_rrset_t * rr, uint8_t rank, bool to_wire, uint32_t qry_uid, knot_mm_t * pool)`

`int kr_ranked_rrarray_set_wire (ranked_rr_array_t * array, bool to_wire, uint32_t qry_uid, bool check_dups, bool(*extraCheck)(const ranked_rr_array_entry_t*))`

*KR\_PURE* `char* kr_pkt_text (const knot_pkt_t * pkt)`

*KR\_PURE* `char* kr_rrset_text (const knot_rrset_t * rr)`

`static KR_PURE char* kr_dname_text (const knot_dname_t * name)`

`static KR_CONST char* kr_rrtype_text (const uint16_t rrtype)`

*KR\_EXPORT* `char* kr_module_call (struct kr_context * ctx, const char * module, const char * prop, const char * input)`

Call module property.



static uint16\_t **kr\_rrset\_type\_maysig** (const knot\_rrset\_t \* rr)

Return the (covered) type of a nonempty RRset.

static const char\* **lua\_push\_printf** (lua\_State \* L, const char \* fmt, ...)

Printf onto the lua stack, avoiding additional copy (thin wrapper).

static char\* **kr\_straddr** (const struct sockaddr \* addr)

*KR\_EXPORT* uint64\_t **kr\_now** ()

The current time in monotonic milliseconds.

**Note** it may be outdated in case of long callbacks; see uv\_now().

int **knot\_dname\_lf2wire** (knot\_dname\_t \* dst, uint8\_t len, const uint8\_t \* lf)

Convert name from lookup format to wire.

See knot\_dname\_lf

**Note** len bytes are read and len+1 are written with *normal* LF, but it's also allowed that the final zero byte is omitted in LF.

**Return** the number of bytes written (>0) or error code (<0)

static int **kr\_dname\_lf** (uint8\_t \* dst, const knot\_dname\_t \* src, bool add\_wildcard)

Patched knot\_dname\_lf.

LF for "." has length zero instead of one, for consistency. (TODO: consistency?)

**Note** packet is always NULL

#### Parameters

- add\_wildcard: append the wildcard label

## Variables

*KR\_EXPORT* bool **kr\_verbose\_status**

Whether in verbose mode.

Only use this for reading.

*KR\_EXPORT* const char\* **source**

*KR\_EXPORT* const char const char\* **fmt**

const uint8\_t **KEY\_FLAG\_RRSIG** = 0x02

**union inaddr**

*#include <utils.h>* Simple storage for IPx address or AF\_UNSPEC.

## Public Members

struct sockaddr **ip**

struct sockaddr\_in **ip4**

struct sockaddr\_in6 **ip6**

## Defines

`KR_EXPORT`  
`KR_CONST`  
`KR_PURE`  
`KR_NORETURN`  
`KR_COLD`  
`KR_PRINTF` (n)  
`uint`  
`kr_ok`  
`kr_strerror` (x)

## Typedefs

`typedef` unsigned int `uint`

## Functions

static int `KR_COLD kr_error` (int x)

## 4.6.6 Generics library

This small collection of “generics” was born out of frustration that I couldn’t find no such thing for C. It’s either bloated, has poor interface, null-checking is absent or doesn’t allow custom allocation scheme. BSD-licensed (or compatible) code is allowed here, as long as it comes with a test case in `tests/test_generics.c`.

- `array` - a set of simple macros to make working with dynamic arrays easier.
- `map` - a Crit-bit tree key-value map implementation (public domain) that comes with tests.
- `set` - set abstraction implemented on top of map.
- `pack` - length-prefixed list of objects (i.e. array-list).
- `lru` - LRU-like hash table

### `array`

A set of simple macros to make working with dynamic arrays easier.

```
MIN(array_push(arr, val), other)
```

**Note** The C has no generics, so it is implemented mostly using macros. Be aware of that, as direct usage of the macros in the evaluating macros may lead to different expectations:

May evaluate the code twice, leading to unexpected behaviour. This is a price to pay for the absence of proper generics.

*Example usage:*

```

array_t(const char*) arr;
array_init(arr);

// Reserve memory in advance
if (array_reserve(arr, 2) < 0) {
    return ENOMEM;
}

// Already reserved, cannot fail
array_push(arr, "princess");
array_push(arr, "leia");

// Not reserved, may fail
if (array_push(arr, "han") < 0) {
    return ENOMEM;
}

// It does not hide what it really is
for (size_t i = 0; i < arr.len; ++i) {
    printf("%s\n", arr.at[i]);
}

// Random delete
array_del(arr, 0);

```

## Defines

### **array\_t** (type)

Declare an array structure.

### **array\_init** (array)

Zero-initialize the array.

### **array\_clear** (array)

Free and zero-initialize the array.

### **array\_clear\_mm** (array, free, baton)

### **array\_reserve** (array, n)

Reserve capacity up to 'n' bytes.

**Return** 0 if success, <0 on failure

### **array\_reserve\_mm** (array, n, reserve, baton)

### **array\_push** (array, val)

Push value at the end of the array, resize it if necessary.

**Note** May fail if the capacity is not reserved.

**Return** element index on success, <0 on failure

### **array\_pop** (array)

Pop value from the end of the array.

### **array\_del** (array, i)

Remove value at given index.

**Return** 0 on success, <0 on failure

**array\_tail** (array)

Return last element of the array.

**Warning** Undefined if the array is empty.

### Functions

static size\_t **array\_next\_count** (size\_t want)

Simplified Qt containers growth strategy.

static int **array\_std\_reserve** (void \* baton, char \*\* mem, size\_t elm\_size, size\_t want, size\_t \* have)

static void **array\_std\_free** (void \* baton, void \* p)

### map

A Crit-bit tree key-value map implementation.

*Example usage:*

**Warning** If the user provides a custom allocator, it must return addresses aligned to 2B boundary.

```
map_t map = map_make(NULL);

// Custom allocator (optional)
map.malloc = &mymalloc;
map.baton = &mymalloc_context;

// Insert k-v pairs
int values = { 42, 53, 64 };
if (map_set(&map, "princess", &values[0]) != 0 ||
    map_set(&map, "prince", &values[1]) != 0 ||
    map_set(&map, "leia", &values[2]) != 0) {
    fail();
}

// Test membership
if (map_contains(&map, "leia")) {
    success();
}

// Prefix search
int i = 0;
int count(const char *k, void *v, void *ext) { (*(int *)ext)++; return 0; }
if (map_walk_prefixed(map, "princ", count, &i) == 0) {
    printf("%d matches\n", i);
}

// Delete
if (map_del(&map, "badkey") != 0) {
    fail(); // No such key
}

// Clear the map
map_clear(&map);
```

## Defines

**map\_walk** (*map*, callback, baton)

## Functions

static **map\_t** **map\_make** (struct knot\_mm \* *pool*)

Creates an new empty critbit map.

Pass NULL for malloc+free.

int **map\_contains** (*map\_t* \* *map*, const char \* *str*)

Returns non-zero if map contains str.

void\* **map\_get** (*map\_t* \* *map*, const char \* *str*)

Returns value if map contains str.

Note: NULL may mean two different things.

int **map\_set** (*map\_t* \* *map*, const char \* *str*, void \* *val*)

Inserts str into map.

Returns 0 if new, 1 if replaced, or ENOMEM.

int **map\_del** (*map\_t* \* *map*, const char \* *str*)

Deletes str from the map, returns 0 on success.

void **map\_clear** (*map\_t* \* *map*)

Clears the given map.

int **map\_walk\_prefixed** (*map\_t* \* *map*, const char \* *prefix*, int(\**callback*)(const char \*, void \*, void \*),  
void \* *baton*)

Calls callback for all strings in map with the given prefix.

Returns value immediately if a callback returns nonzero.

### Parameters

- *map*:
- *prefix*: required string prefix (empty => all strings)
- *callback*: callback parameters are (key, value, baton)
- *baton*: passed uservalue

**struct map\_t**

*#include* <map.h> Main data structure.

### Public Members

void\* **root**

struct knot\_mm\* **pool**

### set

A set abstraction implemented on top of map.

*Example usage:*

**Note** The API is based on map.h, see it for more examples.

```
set_t set = set_make(NULL);

// Insert keys
if (set_add(&set, "princess") != 0 ||
    set_add(&set, "prince") != 0 ||
    set_add(&set, "leia") != 0) {
    fail();
}

// Test membership
if (set_contains(&set, "leia")) {
    success();
}

// Prefix search
int i = 0;
int count(const char *s, void *n) { (*(int *)n)++; return 0; }
if (set_walk_prefixed(set, "princ", count, &i) == 0) {
    printf("%d matches\n", i);
}

// Delete
if (set_del(&set, "badkey") != 0) {
    fail(); // No such key
}

// Clear the set
set_clear(&set);
```

### Defines

#### **set\_make**

Creates a new, empty critbit set

#### **set\_contains** (set, str)

Returns non-zero if set contains str

#### **set\_add** (set, str)

Inserts str into set. Returns 0 if new, 1 if already present, or ENOMEM.

#### **set\_del** (set, str)

Deletes str from the set, returns 0 on success

#### **set\_clear** (set)

Clears the given set

#### **set\_walk** (set, callback, baton)

Calls callback for all strings in map

#### **set\_walk\_prefixed** (set, prefix, callback, baton)

Calls callback for all strings in set with the given prefix

## Typedefs

```
typedef map_t set_t
```

```
typedef int( set_walk_cb)(const char *, void *)
```

## pack

A length-prefixed list of objects, also an array list.

Each object is prefixed by item length, unlike array this structure permits variable-length data. It is also equivalent to forward-only list backed by an array.

*Example usage:*

**Note** Maximum object size is  $2^{16}$  bytes, see [pack\\_objlen\\_t](#) If some mistake happens somewhere, the access may end up in an infinite loop. (equality comparison on pointers)

```
pack_t pack;
pack_init(pack);

// Reserve 2 objects, 6 bytes total
pack_reserve(pack, 2, 4 + 2);

// Push 2 objects
pack_obj_push(pack, U8("jedi"), 4)
pack_obj_push(pack, U8("\xbe\xef"), 2);

// Iterate length-value pairs
uint8_t *it = pack_head(pack);
while (it != pack_tail(pack)) {
    uint8_t *val = pack_obj_val(it);
    it = pack_obj_next(it);
}

// Remove object
pack_obj_del(pack, U8("jedi"), 4);

pack_clear(pack);
```

## Defines

**pack\_init** (pack)

Zero-initialize the pack.

**pack\_clear** (pack)

Free and the pack.

**pack\_clear\_mm** (pack, free, baton)

**pack\_reserve** (pack, objs\_count, objs\_len)

Incrementally reserve objects in the pack.

**pack\_reserve\_mm** (pack, objs\_count, objs\_len, reserve, baton)

**pack\_head** (pack)

Return pointer to first packed object.

**pack\_tail** (pack)  
Return pack end pointer.

## Typedefs

**typedef** uint16\_t **pack\_objlen\_t**  
Packed object length type.

## Functions

**typedef** **array\_t** (uint8\_t)  
Pack is defined as an array of bytes.

static **pack\_objlen\_t** **pack\_obj\_len** (uint8\_t \* *it*)  
Return packed object length.

static uint8\_t\* **pack\_obj\_val** (uint8\_t \* *it*)  
Return packed object value.

static uint8\_t\* **pack\_obj\_next** (uint8\_t \* *it*)  
Return pointer to next packed object.

static uint8\_t\* **pack\_last** (pack\_t *pack*)  
Return pointer to the last packed object.

static int **pack\_obj\_push** (pack\_t \* *pack*, const uint8\_t \* *obj*, **pack\_objlen\_t** *len*)  
Push object to the end of the pack.

**Return** 0 on success, negative number on failure

static uint8\_t\* **pack\_obj\_find** (pack\_t \* *pack*, const uint8\_t \* *obj*, **pack\_objlen\_t** *len*)  
Returns a pointer to packed object.

**Return** pointer to packed object or NULL

static int **pack\_obj\_del** (pack\_t \* *pack*, const uint8\_t \* *obj*, **pack\_objlen\_t** *len*)  
Delete object from the pack.

**Return** 0 on success, negative number on failure

## lru

A lossy cache.

*Example usage:*

**Note** The implementation tries to keep frequent keys and avoid others, even if “used recently”, so it may refuse to store it on *lru\_get\_new()*. It uses hashing to split the problem pseudo-randomly into smaller groups, and within each it tries to approximate relative usage counts of several most frequent keys/hashees. This tracking is done for *more* keys than those that are actually stored.



```

// Define new LRU type
typedef lru_t(int) lru_int_t;

// Create LRU
lru_int_t *lru;
lru_create(&lru, 5, NULL);

// Insert some values
int *pi = lru_get_new(lru, "luke", strlen("luke"));
if (pi)
    *pi = 42;
pi = lru_get_new(lru, "leia", strlen("leia"));
if (pi)
    *pi = 24;

// Retrieve values
int *ret = lru_get_try(lru, "luke", strlen("luke"));
if (!ret) printf("luke dropped out!\n");
else printf("luke's number is %d\n", *ret);

char *enemies[] = {"goro", "raiden", "subzero", "scorpion"};
for (int i = 0; i < 4; ++i) {
    int *val = lru_get_new(lru, enemies[i], strlen(enemies[i]));
    if (val)
        *val = i;
}

// We're done
lru_free(lru);

```

## Defines

### **lru\_t** (type)

The type for LRU, parametrized by value type.

### **lru\_create** (ptable, max\_slots, mm\_ctx\_array, mm\_ctx)

Allocate and initialize an LRU with default associativity.

The real limit on the number of slots can be a bit larger but less than double.

**Note** The pointers to memory contexts need to remain valid during the whole life of the structure (or be NULL).

#### Parameters

- `ptable`: pointer to a pointer to the LRU
- `max_slots`: number of slots
- `mm_ctx_array`: memory context to use for the huge array, NULL for default
- `mm_ctx`: memory context to use for individual key-value pairs, NULL for default

### **lru\_free** (table)

Free an LRU created by `lru_create` (it can be NULL).

### **lru\_reset** (table)

Reset an LRU to the empty state (but preserve any settings).

**lru\_get\_try** (table, key\_, len\_)

Find key in the LRU and return pointer to the corresponding value.

**Return** pointer to data or NULL if not found

**Parameters**

- table: pointer to LRU
- key\_: lookup key
- len\_: key length

**lru\_get\_new** (table, key\_, len\_, res)

Return pointer to value, inserting if needed (zeroed).

**Return** pointer to data or NULL (can be even if memory could be allocated!)

**Parameters**

- table: pointer to LRU
- key\_: lookup key
- len\_: key length
- res: pointer to bool to store result of operation (true if entry is newly added, false otherwise; can be NULL).

**lru\_apply** (table, function, baton)

Apply a function to every item in LRU.

**Parameters**

- table: pointer to LRU
- function: enum lru\_apply\_do (\*function)(const char \*key, uint len, val\_type \*val, void \*baton)  
See enum lru\_apply\_do for the return type meanings.
- baton: extra pointer passed to each function invocation

**lru\_capacity** (table)

Return the real capacity - maximum number of keys holdable within.

**Parameters**

- table: pointer to LRU

## Enums

**enum lru\_apply\_do**

Possible actions to do with an element.

*Values:*

**LRU\_APPLY\_DO\_NOTHING**

**LRU\_APPLY\_DO\_EVICT**

## Functions

static *uint* **round\_power** (*uint* size, *uint* power)  
Round the value up to a multiple of (1 << power).



- *Supported languages*
- *The anatomy of an extension*
- *Writing a module in Lua*
- *Writing a module in C*
- *Writing a module in Go*
- *Configuring modules*
- *Exposing C/Go module properties*

## 5.1 Supported languages

Currently modules written in C and LuaJIT are supported. There is also a support for writing modules in Go 1.5+ — the library has no native Go bindings, library is accessible using `CGO`.

## 5.2 The anatomy of an extension

A module is a shared object or script defining specific functions, here's an overview.

*Note* — the *Modules* header documents the module loading and API.

C/Go	Lua	Params	Comment
X_api() <sup>1</sup>			API version
X_init()	X.init()	module	Constructor
X_deinit()	X.deinit()	module, key	Destructor
X_config()	X.config()	module	Configuration
X_layer()	X.layer	module	<i>Module layer</i>
X_props()			List of properties

The X corresponds to the module name, if the module name is `hints`, then the prefix for constructor would be `hints_init()`. This doesn't apply for Go, as it for now always implements *main* and requires capitalized first letter in order to export its symbol.

---

**Note:** The resolution context struct `kr_context` holds loaded modules for current context. A module can be registered with `kr_context_register()`, which triggers module constructor *immediately* after the load. Module destructor is automatically called when the resolution context closes.

If the module exports a layer implementation, it is automatically discovered by `kr_resolver()` on resolution init and plugged in. The order in which the modules are registered corresponds to the call order of layers.

---

## 5.3 Writing a module in Lua

The probably most convenient way of writing modules is Lua since you can use already installed modules from system and have first-class access to the scripting engine. You can also tap to all the events, that the C API has access to, but keep in mind that transitioning from the C to Lua function is slower than the other way round.

---

**Note:** The Lua functions retrieve an additional first parameter compared to the C counterparts - a "state". There is no Lua wrapper for C structures used in the resolution context, until they're implemented you can inspect the structures using the `ffi` library.

---

The modules follow the [Lua way](#), where the module interface is returned in a named table.

```

--- @module Count incoming queries
local counter = {}

function counter.init(module)
    counter.total = 0
    counter.last = 0
    counter.failed = 0
end

function counter.deinit(module)
    print('counted', counter.total, 'queries')
end

-- @function Run the q/s counter with given interval.
function counter.config(conf)
    -- We can use the scripting facilities here
    if counter.ev then event.cancel(counter.ev)

```

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---

<sup>1</sup> Mandatory symbol.

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```

event.recurrent(conf.interval, function ()
    print(counter.total - counter.last, 'q/s')
    counter.last = counter.total
end)
end
return counter

```

**Tip:** The API functions may return an integer value just like in other languages, but they may also return a coroutine that will be continued asynchronously. A good use case for this approach is a deferred initialization, e.g. loading a chunks of data or waiting for I/O.

```

function counter.init(module)
    counter.total = 0
    counter.last = 0
    counter.failed = 0
    return coroutine.create(function ()
        for line in io.lines('/etc/hosts') do
            load(module, line)
            coroutine.yield()
        end
    end)
end
end

```

The created module can be then loaded just like any other module, except it isn't very useful since it doesn't provide any layer to capture events. The Lua module can however provide a processing layer, just *like its C counterpart*.

```

-- Notice it isn't a function, but a table of functions
counter.layer = {
    begin = function (state, data)
        counter.total = counter.total + 1
        return state
    end,
    finish = function (state, req, answer)
        if state == kres.FAIL then
            counter.failed = counter.failed + 1
        end
        return state
    end
}

```

Since the modules are like any other Lua modules, you can interact with them through the CLI and any interface.

**Tip:** The module can be placed anywhere in the Lua search path, in the working directory or in the MODULESDIR.

## 5.4 Writing a module in C

As almost all the functions are optional, the minimal module looks like this:

```
#include "lib/module.h"
/* Convenience macro to declare module API. */
KR_MODULE_EXPORT(mymodule);
```

Let's define an observer thread for the module as well. It's going to be stub for the sake of brevity, but you can for example create a condition, and notify the thread from query processing by declaring module layer (see the *Writing layers*).

```
static void* observe(void *arg)
{
    /* ... do some observing ... */
}

int mymodule_init(struct kr_module *module)
{
    /* Create a thread and start it in the background. */
    pthread_t thr_id;
    int ret = pthread_create(&thr_id, NULL, &observe, NULL);
    if (ret != 0) {
        return kr_error(errno);
    }

    /* Keep it in the thread */
    module->data = thr_id;
    return kr_ok();
}

int mymodule_deinit(struct kr_module *module)
{
    /* ... signalize cancellation ... */
    void *res = NULL;
    pthread_t thr_id = (pthread_t) module->data;
    int ret = pthread_join(thr_id, res);
    if (ret != 0) {
        return kr_error(errno);
    }

    return kr_ok();
}
```

This example shows how a module can run in the background, this enables you to, for example, observe and publish data about query resolution.

## 5.5 Writing a module in Go

The Go modules use `CGO` to interface C resolver library, there are no native bindings yet. Second issue is that layers are declared as a structure of function pointers, which are **not present in Go**, the workaround is to declare them in `CGO` header. Each module must be the `main` package, here's a minimal example:

```
package main

/*
#include "lib/module.h"
*/
import "C"
```

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```
import "unsafe"

/* Mandatory functions */

//export mymodule_api
func mymodule_api() C.uint32_t {
    return C.KR_MODULE_API
}
func main() {}
```

**Warning:** Do not forget to prefix function declarations with `//export symbol_name`, as only these will be exported in module.

In order to integrate with query processing, you have to declare a helper function with function pointers to the layer implementation. Since the code prefacing `import "C"` is expanded in headers, you need the *static inline* trick to avoid multiple declarations. Here's how the preface looks like:

```
/*
#include "lib/layer.h"
#include "lib/module.h"
// Need a forward declaration of the function signature
int finish(kr_layer_t *);
// Workaround for layers composition
static inline const kr_layer_api_t *_layer(void)
{
    static const kr_layer_api_t api = {
        .finish = &finish
    };
    return &api;
}
*/
import "C"
import "unsafe"
```

Now we can add the implementations for the `finish` layer and finalize the module:

```
//export finish
func finish(ctx *C.kr_layer_t) C.int {
    // Since the context is unsafe.Pointer, we need to cast it
    var param *C.struct_kr_request = (*C.struct_kr_request)(ctx.data)
    // Now we can use the C API as well
    fmt.Printf("[go] resolved %d queries\n", C.list_size(&param.rplan.resolved))
    return 0
}

//export mymodule_layer
func mymodule_layer(module *C.struct_kr_module) *C.kr_layer_api_t {
    // Wrapping the inline trampoline function
    return C._layer()
}
```

See the [CGO](#) for more information about type conversions and interoperability between the C/Go.

### 5.5.1 Gotchas

- `main()` function is mandatory in each module, otherwise it won't compile.
- Module layer function implementation must be done in C during `import "C"`, as Go doesn't support pointers to functions.
- The library doesn't have a Go-ified bindings yet, so interacting with it requires CGO shims, namely structure traversal and type conversions (strings, numbers).
- Other modules can be called through C call `C.kr_module_call(kr_context, module_name, module_property, input)`

## 5.6 Configuring modules

There is a callback `X_config()` that you can implement, see `hints` module.

## 5.7 Exposing C/Go module properties

A module can offer NULL-terminated list of *properties*, each property is essentially a callable with free-form JSON input/output. JSON was chosen as an interchangeable format that doesn't require any schema beforehand, so you can do two things - query the module properties from external applications or between modules (i.e. *statistics* module can query *cache* module for memory usage). JSON was chosen not because it's the most efficient protocol, but because it's easy to read and write and interface to outside world.

---

**Note:** The `void *env` is a generic module interface. Since we're implementing daemon modules, the pointer can be cast to `struct engine*`. This is guaranteed by the implemented API version (see *Writing a module in C*).

---

Here's an example how a module can expose its property:

```
char* get_size(void *env, struct kr_module *m,
              const char *args)
{
    /* Get cache from engine. */
    struct engine *engine = env;
    struct kr_cache *cache = &engine->resolver.cache;
    /* Read item count */
    int count = (cache->api)->count(cache->db);
    char *result = NULL;
    asprintf(&result, "{ \"result\": %d }", count);

    return result;
}

struct kr_prop *cache_props(void)
{
    static struct kr_prop prop_list[] = {
        /* Callback, Name, Description */
        {&get_size, "get_size", "Return number of records."},
        {NULL, NULL, NULL}
    };
    return prop_list;
}
```

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```
}  
  
KR_MODULE_EXPORT(cache)
```

Once you load the module, you can call the module property from the interactive console. *Note* — the JSON output will be transparently converted to Lua tables.

```
$ kresd  
...  
[system] started in interactive mode, type 'help()'  
> modules.load('cached')  
> cached.get_size()  
[size] => 53
```

*Note* — this relies on function pointers, so the same `static inline` trick as for the `Layer()` is required for C/Go.

### 5.7.1 Special properties

If the module declares properties `get` or `set`, they can be used in the Lua interpreter as regular tables.



## CHAPTER 6

---

### Indices and tables

---

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- `modindex`
- `search`



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