A DNS Resolver

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Domain Name System

RFC 1035

```
             Local Host                        |  Foreign
                                               |
+---------+               +----------+         |  +--------+
|         | user queries  |          |queries  |  |        |
|  User   |-------------->|          |---------|->|Foreign |
| Program |               | Resolver |         |  |  Name  |
|         |<--------------|          |<--------|--| Server |
|         | user responses|          |responses|  |        |
+---------+               +----------+         |  +--------+
                            |     A            |
            cache additions |     | references |
                            V     |            |
                          +----------+         |
                          |  cache   |         |
                          +----------+         |
```

the resolver

- client: sends request to resolver
- resolver: receives requests, queries servers/resolvers and caches responses
- server: responsible for sub-domain

The first resolver is most probably running on your laptop.

let's build a DNS resolver

```
defmodule  DNS do

  @server {8,8,8,8}
  @port 53
  @local 5300

  def start() do
    start(@local, @server, @port)
  end

  def start(local, server, port) do
    spawn(fn() -> init(local, server, port) end)
  end
```

The server is the DNS server to which queries are routed.

two datagram sockets

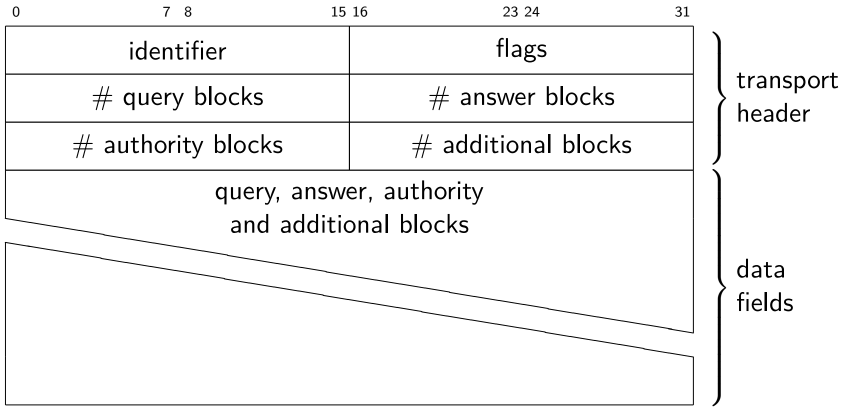
```
def init(local, server, port) do
  case :gen_udp.open(local, [{:active, true}, :binary]) do
    {:ok, local} ->
      case :gen_udp.open(0, [{:active, true}, :binary]) do
        {:ok, remote} ->
          dns(local, remote, server, port)
        error ->
          :io.format("DNS error opening remote socket: ~w~n", [error])
      end
    error ->
      :io.format("DNS error opening local socket: ~w~n", [error])
  end
end
```

the server loop

```
  def dns(local, remote, server, port) do
    receive do
      {:udp, ^local, _client, _client_port, _msg} ->
        dns(local, remote, server, port)
      :stop ->
        :ok
      :update ->
        DNS.dns(local, remote, server, port)
      strange ->
        :io.format("strange message ~w~n", [strange])
        dns(local, remote, server, port)
    end
  end
```

Let's try.

let's decode the message



0 7 8 15 16 23 24 31

identifier	flags
# query blocks	# answer blocks
# authority blocks	# additional blocks

query, answer, authority and additional blocks

transport header

data fields

Query and response messages of the same format.

message flags

- QR: query or reply
- Op-code: the operation
- AA: authoritative answer (if the server is responsible for the domain)
- TC: message truncated, more to follow
- RD: recursion desired by client
- RA: recursion available by server
- Resp-code: ok or error message in response

0	1 4	5	6	7	8	9 11	12 15
QR	Op-code	AA	TC	RD	RA	-	Resp-code

This is getting complicated.

the bit syntax

```
def decode(<<id::16, flags::binary-size(2),
             qdc::16, anc::16,
             ncs::16, arc::16,
             body::binary>>=raw) do

    <<qr::1, op::4, aa::1, tc::1, rd::1, ra::1, _::3, resp::4>> = flags

    decoded = decode_body(qdc, anc, ncs, arc, body, raw)

    {id, qr, op, aa, tc, rd, ra, rcode, decoded}
end
```

Why passing the raw message to the decoding of the body?

decode the body

The body consists of a number of: query, response, authoritative (server node) and additional sections.

The answer, authoritative and additional sections follow the same pattern, the query is slightly different.

```
decode_body(qdc, anc, nsc, arc, body, raw) do
    {query, rest} = decode_query(qdc, body, raw)
    {answer, rest} = decode_answer(anc, rest, raw)
    {authority, rest} = decode_answer(nsc, rest, raw)
    {additional, _} = decode_answer(arc, rest, raw)
    {query, answer, authority, additional}
end
```

Note the nestling of the reminder of the body.

decode a query

A query consists of a sequence of queries (we know from the header how many).

⟨*query*⟩ ::= <name> <query type> <query class>

⟨*name*⟩ ::= <empty> | <label> <name>

⟨*empty*⟩ ::= *8 bits* 0

⟨*label*⟩ ::= <length> <byte sequence of length>

⟨*query type*⟩ ::= *16 bits* (1 = A, ... 15 = MX, 16 = TXT, ...)

⟨*query class*⟩ ::= *16 bits* (1 = Internet)

⟨*length*⟩ ::= *8 bits* (0..63 i.e. the two highest bits are set to zero)

decode a query

```
def decode_query(0, body, _) do
  {[], body}
end
def decode_query(n, body, raw) do
  {name, <<qtype::16, qclass::16, rest::binary>>} = decode_name(body, raw)
  {decoded, rest} = decode_query(n-1, rest, raw),
  {[{name, qtype, qclass} | decoded], rest}
end
```

decode a name

```
def decode_name(label, raw) do
  decode_name(label, [], raw)
end

def decode_name(<<0::1, 0::1, 0::6, rest::binary>>, names, _raw) do
  {Enum.reverse(names), rest}
end

def decode_name(<<0::1, 0::1, n::6, _::binary>> = label, names, raw) do
  <<_::8, name::binary-size(n), rest::binary>> = label
  decode_name(rest, [name|names], raw)
end
```

query example

Erlang binary:

```
<<4,12, 1, 0,
  0, 1, 0, 0,
  0, 0, 0, 0,
  3,119,119,119,3,107,116,104,2,115,101,0,
  0,1,0,1>>
```

Decoded query:

```
{1036,0,0,0,0,1,0,0,{[{['www','kth','se'],1,1}],[],[],[]}}
```

encoding names by offset

The names in answers may use a more compact form of encoding.

Assume we have encoded `www.kth.se` and need to encode `mail.kth.se` - then we can reuse the coding of `kth.se`.

⟨*label*⟩ ::= <length> <byte sequence of length n> |
<offset>

⟨*offset*⟩ ::= *16 bits* (two highest bits set to ones)

The length version will always have the top two bits set to 00 *and the offset version will have them set to* 11.

offset encoding

```
  def decode_names(<<1::1, 1::1, n::14, rest::binary>>, names, raw) do
    ## offset encoding
    <<_::binary-size(n), section::binary>> = raw
    {name, _} = decode_names(section, names, raw)
    {name, rest}
  end
end
```

decode an answer

All answer sections have the same basic structure:

$\langle \textit{answer} \rangle$ ::= $\langle \textit{name} \rangle$ $\langle \textit{type} \rangle$ $\langle \textit{class} \rangle$ $\langle \textit{ttl} \rangle$ $\langle \textit{length} \rangle$ $\langle \textit{resource record} \rangle$

- type 16-bits: A-type, NS-, CNAME-, MX- etc
- class 16-bits: Internet, ...
- TTL 32-bits: time in seconds (typical some hours)
- length 16-bits: the length of the record in bytes

The resource record is coded depending on the type of resource.

let's try

forward the reply