How we are developing a next generation DNS API for applications

Sara Dickinson
Sinodun

Willem Toorop
NLnet Labs

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getdns
Unbound security

Introduction

- Present an implementation of the *getdns* API
- Why is a new DNS API needed?
- Goals and evolution
- Key Features (for Applications and for DNS)
  - Practical Examples
  - DNS is a moving target – research tool

getdns overview

- *getdns* is a modern asynchronous DNS API
- Designed by and for application developers
- First specification by Paul Hoffman 2013
- First Open Source implementation developed by a collaborative effort:
  - Verisign Labs, NLnet Labs
  - No Mountain, Sinodun

BIG NEWS: 1.0.0b1 is now available!

getdns overview

- Offers stub and full recursive mode (libunbound)
- All record types and fine-grained access to response
- DNSSEC validation (even in stub mode)

More details later...

- Supports DNS Privacy (DNS-over-TLS)

- Implemented in C with bindings: Python, nodejs, Java, PHP
- Homepage: https://getdnsapi.net/
- Spec: https://getdnsapi.net/spec.html

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Why was it needed?

- Default OS DNS resolver libraries (getaddrinfo(), getnameinfo()) are slow to evolve and don't support modern DNS capabilites

DNSSEC/DANE, DNS Privacy, ASYNC

- **Catch 22**: No nice APIs for applications, no uptake of new features, no drivers for deployment…

- **Light Bulb moment**: API's were designed by and for DNS folks!

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Goals

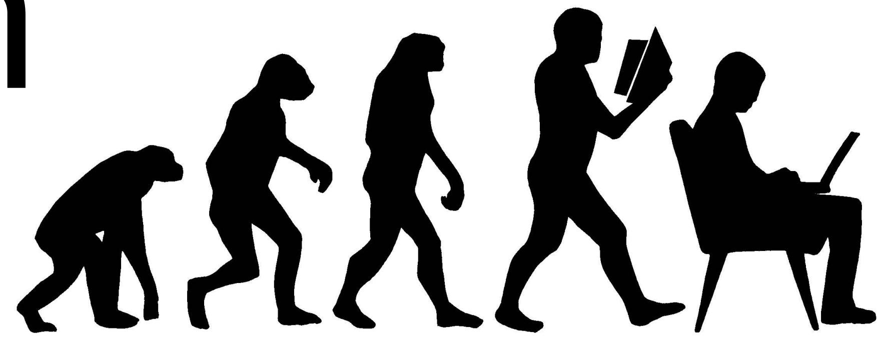
- Goal of *getdns*

… API design from talking to application developers …

… create a natural follow-on to getaddrinfo()

“a particular hope is to inspire application developers towards innovative security solutions in their applications”

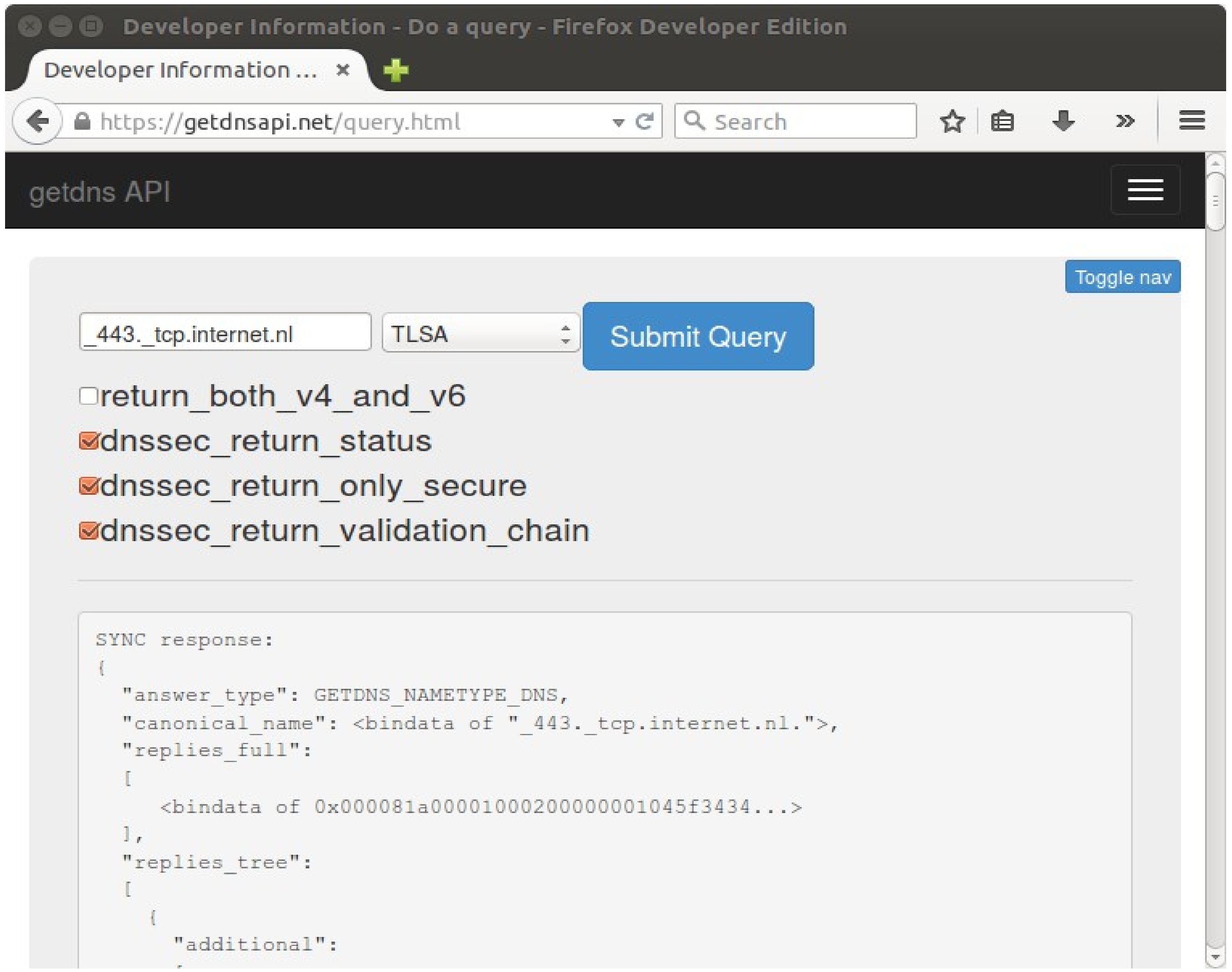
Evolution



- Core dev team, that has owned the spec since 2014
- Bindings have evolved with core code and spec
- Code taken to multiple Hackathons/conferences to get direct feedback from application developers
  - TNW (The Next Web), W3C, PyCon, IETF
- Discussions with mobile and embedded platforms to understand needs (minimal dependancies)

Key features

https://getdnsapi.net/query.html


Developer Information - Do a query - Firefox Developer Edition
Developer Information ...
https://getdnsapi.net/query.html
Search
getdns API
Toggle nav
_443._tcp.internet.nl
TLSA
Submit Query

☐ return_both_v4_and_v6
☑ dnssec_return_status
☑ dnssec_return_only_secure
☑ dnssec_return_validation_chain

```
SYNC response:
{
  "answer_type": GETDNS_NAMETYPE_DNS,
  "canonical_name": <bindata of "_443._tcp.internet.nl.">,
  "replies_full":
  [
     <bindata of 0x000081a000010002000000001045f3434...>
  ],
  "replies_tree":
  [
    {
      "additional":
```

- Overview of features
  - Requirements
  - Solution

What Application Developers Want

- **Async by default. Why?**
  - Modern applications organized around events
    - File system and Network IO
    - User interaction
    - Start looking up names in advance
    - Schedule requests in parallel
  - Spin on an event loop

What Application Developers Want

- **Async by default in getdns**
  - Requests are scheduled
  - No 'execution' *(i.e. no 'run event loop')*

from the spec ...

> *"Each implementation of the DNS API will specify an extension function that tells the DNS context which event base is being used"*

  - We provide extensions for libevent, libev, libuv

getdns_address

```
getdns_return_t getdns_address(
    getdns_context          *context,
    const char              *name,
    getdns_dict             *extensions,
    void                    *userarg,
    getdns_transaction_t    *transaction_id,
    getdns_callback_t        callbackfn
);

typedef void (*getdns_callback_t)(
    getdns_context          *context,
    getdns_callback_type_t   callback_type,
    getdns_dict             *response,
    void                    *userarg,
    getdns_transaction_t     transaction_id
);
```

getdns context

extensions dict

COMPLETE, CANCEL,
TIMEOUT or ERROR

response dict

getdns: nodejs bindings

Seamlessly hook into the environments (language) native event system
Example: Async setup of TLS connection and TLSA fetch

```
function setup_tls(conn, err, res)
{
   conn.socket = tls.connect(443, {host res.just_address_answers[0]
                                  ,rejectUnauthorized: false
                                  ,servername:conn.name }
                                  ,function() { verify_tlsa(conn, null, null)});
}

var conn = { name: 'getdnsapi.net', socket: null, tlsa_rrs: null};

ctx = getdns.createContext();

ctx.address( conn.name, function(err, res) { setup_tls(conn, err, res) });

ctx.general( '_443._tcp.' + conn.name, getdns.RRTYPE_TLSA
           , { dnssec_return_only_secure: true }
           , function(err, res) { verify_tlsa(conn, err, res) })
```

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What Application Developers Want

- **Hand control to the application**

CRUCIAL for Integration
- nodejs
- Windows

  - Custom/User defined Event Loops
    - *From getdns version 1.0.0beta and upwards linked against libunbound version 1.5.9 and upwards:*

Event loop is also propagated to recursive resolution

  - Custom/User defined Memory Management
  - See Appendix for details of both

What Application Developers Want

- **JSON dict like interfaces to DNS data. Why?**
  - Makes programming easy – you see what's there

OUTPUT: response dictionary

```
{
 "answer_type": GETDNS_NAMETYPE_DNS,
 "status": GETDNS_RESPSTATUS_GOOD,
 "canonical_name": <bindata of "www.getdnsapi.net.">,
 "just_address_answers":
 [ { "address_data": <bindata for 185.49.141.37>,
     "address_type": <bindata of "IPv4">
   },
   { "address_data": <bindata for 2a04:b900:0:100::37>,
     "address_type": <bindata of "IPv6">
   }
 ],
 "replies_full":
 [
   <bindata of 0x00008180000100020004000103777777...>,
   <bindata of 0x00008180000100020004000903777777...>
 ],
 "replies_tree":
 [
   { ... first reply ... },
   { ... second reply ... },
```

getdns: JSON dict

- **JSON dict like interfaces to DNS data. Why?**
  - Makes programming easy – you see what's there

OUTPUT: response dictionary – replies trees

```
"replies_tree":
[
 { "header" : { "qdcount": 1, "ancount": 2, "rd": 1, "ra": 1,
             "opcode": GETDNS_OPCODE_QUERY,
             "rcode" : GETDNS_RCODE_NOERROR, ... },

  "question": { "qname" : <bindata for www.getdnsapi.net.>,
              "qtype" : GETDNS_RRTYPE_A
              "qclass": GETDNS_RRCLASS_IN, },

  "answer"  : [ { "name" : <bindata for www.getdnsapi.net.>,
               "type" : GETDNS_RRTYPE_A,
               "class": GETDNS_RRCLASS_IN,
               "rdata": { "ipv4_address": <bindata for 185.49.141.37>,
                       "rdata_raw": <bindata of 0xb9318d25> },
              }, ...
  "authority": [ ... ],
  "additional": [],
  "canonical_name": <bindata of "www.getdnsapi.net.">,
  "answer_type": GETDNS_NAMETYPE_DNS
 },
 { "header" : { ...
```

getdns: JSON dict

- **JSON dict like interfaces to DNS data. Why?**
- Extensible (allows experimentation)

INPUT: extensions dictionary

```
{
  "dnssec_return_validation_chain": GETDNS_EXTENSION_TRUE,
  "specify_class": GETDNS_CLASS_HS,
  "add_opt_parameters":
  { "maximum_udp_payload_size": 1232,
    "options":
     [ { "option_code": 10,
         "option_data": cookie_bindata } ]
  }
}
```

getdns: JSON dict

- **JSON dict like interfaces to DNS data.**
  - *(almost)* all data is in wire format
  - The bindata's just point to the right spot in the packet *(JIT potential)*

OUTPUT: response dictionary

```
"replies_tree":
[
 { "header" : { "qdcount": 1, "ancount": 2, "rd": 1, "ra": 1,
              "opcode": GETDNS_OPCODE_QUERY,
              "rcode" : GETDNS_RCODE_NOERROR, ... },

   "question": { "qname" : <bindata for www.getdnsapi.net.>,
               "qtype" : GETDNS_RRTYPE_A
               "qclass": GETDNS_RRCLASS_IN, },

   "answer"  : [ { "name" : <bindata for www.getdnsapi.net.>,
                 "type" : GETDNS_RRTYPE_A,
                 "class": GETDNS_RRCLASS_IN,
                 "rdata": { "ipv4_address": <bindata for 185.49.141.37>,
                          "rdata_raw": <bindata of 0xb9318d25> },
               }, ...
   "authority": [ ... ],
   "additional": [],
   "canonical_name": <bindata of "www.getdnsapi.net.">,
   "answer_type": GETDNS_NAMETYPE_DNS
 },
 { "header" : { ...
```

What do C Developers Want

Feedback Not a nice 'C' like interface

- **C-friendly access to JSON dict data**
  - Unconventional, too generic, no type safety
  - Lengthy and repetitive to get to the data in C

```
if ((r = getdns_address_sync(ctx, "getdnsapi.net", ext, &resp)))
        return r;
else if ((r = getdns_dict_get_list(resp, "just_address_answers", &jaa)))
        return r;
else if ((r = getdns_list_get_dict(jaa, 0, &addr_dict)))
        return r;
else if ((r = getdns_list_get_bindata(addr_dict, "address_data", &addr)))
        return r;
```

What do C Developers Want

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        return r;
else if ((r = getdns_list_get_dict(jaa, 0, &addr_dict)))
        return r;
else if ((r = getdns_list_get_bindata(addr_dict, "address_data", &addr)))
        return r;
```

python

```
resp = ctx.address('getdnsapi.net')
addr = resp.just_address_answers[0]['address_data']
```

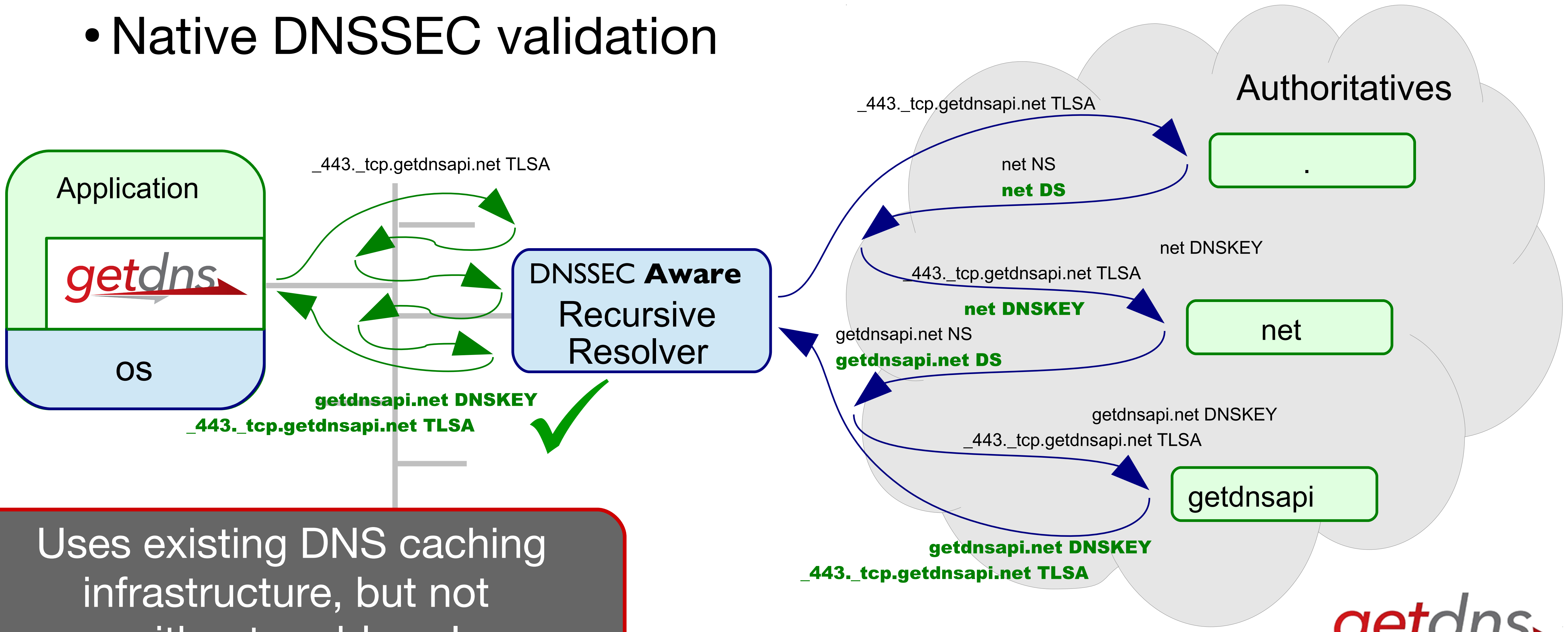
What do C Developers Want

- Since getdns 0.5: **JSON pointer access**
    - Re-wrote examples in the spec – now only 2 lines in C!

```
if ((r = getdns_address_sync(ctx, "getdnsapi.net", ext, &resp)))
        return r;
else if ((r = getdns_dict_get_bindata(resp, "just_address_answers/0/address_data", &addr)))
        return r;
```

What DNS Applications Want

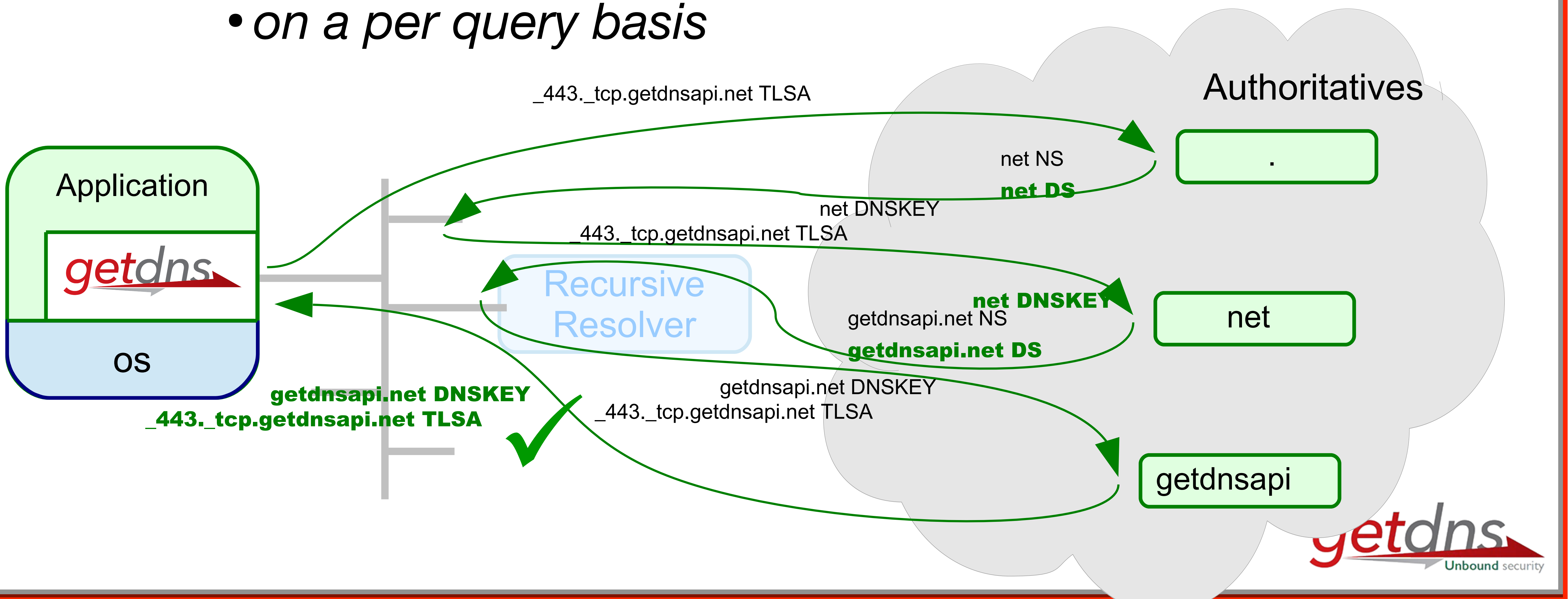
- **DANE**
  - Need DNSSEC to get TLSA, SSHFP, OPENPGPKEY etc.
  - ****Feedback** Validating stub added early**
  - Native DNSSEC validation


Application
getdns
OS
_443._tcp.getdnsapi.net TLSA
DNSSEC Aware Recursive Resolver
getdnsapi.net DNSKEY
_443._tcp.getdnsapi.net TLSA
Authoritatives
_443._tcp.getdnsapi.net TLSA
.
net NS
net DS
net DNSKEY
_443._tcp.getdnsapi.net TLSA
net DNSKEY
net
getdnsapi.net NS
getdnsapi.net DS
getdnsapi.net DNSKEY
_443._tcp.getdnsapi.net TLSA
getdnsapi
getdnsapi.net DNSKEY
_443._tcp.getdnsapi.net TLSA

Uses existing DNS caching infrastructure, but not without problems!

DANE in getdns

- Since getdns 0.5.1: **Roadblock avoidance**
  - Maximise stub usage when possible
  - Fall-back to full recursion when necessary
    - *on a per query basis*



What DNS Applications *will* Want

- **DANE**
  - Need DNSSEC to get TLSA, SSHFP, OPENPGPKEY etc.
  - What else is needed?
    (i.e. still hampering DANE deployment)
    - Verification coming in OpenSSL 1.1.0
    - Future work for this API/library

```
SSL_CTX_dane_enable()
SSL_dane_enable()
SSL_dane_tlsa_add()

See Appendix for
details!
```

Follow redirects to a service (CNAME, MX, SRV)
Collect TLSAs with the reference identifiers
(RFC7671, RFC7672, RFC7673 & RFC6125)

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What DNS Researchers Want

- **DNSSEC API that offers validation functions**
  - Take control of validation
- **Ability to experiment**
  - e.g. Custom code new EDNS0 options
- **Flexible access to responses**
  - Work in progress: DNSSEC transparency
    - draft-shore-tls-dnssec-chain-extension

What getdns offers

- **Unique DNSSEC API**
  - `dnssec_return_validation_chain` extension
  - `getdns_validate_dnssec()` function

- Possible to use getdns to do EDNS0 cookies before implemented

- **Conversion functions:**
  - getdns 0.9.0: *resource record*
  - *getdns 1.0.0b1: complete DNS messages*

Wire format <-> getdns_dict <-> presentation format

DNSSEC validation in getdns

```
getdns_return_t
getdns_validate_dnssec(
        getdns_list *to_validate,
        getdns_list *bundle_of_support_records,
        getdns_list *trust_anchor_records
);
```

```
{ "validation_chain":
  [ { "name" : <bindata for .>, "type": GETDNS_RRTYPE_DNSKEY, ... },
    { "name" : <bindata for .>, "type": GETDNS_RRTYPE_DNSKEY, ... },

    { "name" : <bindata for .>, "type": GETDNS_RRTYPE_RRSIG,
      "rdata": { "signers_name": <bindata for .>,
                 "type_covered": GETDNS_RRTYPE_DNSKEY, ... }, ... },

    { "name" : <bindata for net.>, "type": GETDNS_RRTYPE_DS, ... },
    { "name" : <bindata for net.>, "type": GETDNS_RRTYPE_RRSIG,
      "rdata": { "signers_name": <bindata for .>,
                 "type_covered": GETDNS_RRTYPE_DS, ... }, ... },
```

What meta-data Wants

- **Privacy**
  - Pervasive monitoring (of DNS) is an attack (RFC 7258, RFC 7626.
  - “Specification for DNS over TLS” is now approved as RFC!

- ***getdns***
  - *Transport handling extended from original spec because new specs/standards have emerged (RFC 7766)*
  - Transport list with fallback (TLS, TCP, UPD)
  - TLS authentication possible (2 mechanisms)

- I-D: Padding of DNS message
- I-D: EDNS Client subnet privacy

Conclusions

- Spec development – lessons learned
  - Practical input from users
  - Iterative..
  - Must be prepared to learn and adapt

- Hope is *getdns* will change the way DNS lookups are done by applications

  - Async
  - Increased take up of DNSSEC/DANE
  - Increased use of TCP/TLS

The future

- Small cache for the stub
  (good for DNSSEC, good for roadblock avoidance)
- Sharing upstreams in between contexts
  good for upstreams that keep connections open
- JIT parsing of response dict – some optimisation
- Put the intelligence for doing TLSA lookups (RFC7671, RFC7672 & RFC7673) in *getdns*
- Custom RR types rdata fields with a DNS extension language

The future

- 1.0 release is also a natural transition point
    - Focus to date has been API and implementation
    - Challenge now is deployment and further evolution
- Desire to involve wider community as move forward
    - Call for interested parties to become involved in future of *getdns*
    - Call for ideas for integration into OS distros

Thank you!

https://getdnsapi.net

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Appendix

Appendix – Custom/User Defined Event Loops

- Available by including <getdns/getdns_extra.h>

```
typedef struct getdns_eventloop_vmt getdns_eventloop_vmt;
typedef struct getdns_eventloop {
        getdns_eventloop_vmt *vmt;
        /* object data here */
} getdns_eventloop;


getdns_return_t getdns_context_set_eventloop(
    getdns_context* context, getdns_eventloop *eventloop);


/* Virtual Method Table */
struct getdns_eventloop_vmt {
        void            (*cleanup) (getdns_eventloop *this);
        getdns_return_t (*schedule)(getdns_eventloop *this,
            int fd, uint64_t timeout, getdns_eventloop_event *ev)
        getdns_return_t (*clear)   (getdns_eventloop *this,
            getdns_eventloop_event *ev)
        void            (*run)     (getdns_eventloop *this);
        void            (*run_once)(getdns_eventloop *this, int blocking);
};
```

Appendix - Custom/User Defined Event Loops

```
/* event data */
typedef void (*getdns_eventloop_callback)(void *userarg);
typedef struct getdns_eventloop_event {
        void *userarg;
        getdns_eventloop_callback read_cb;
        getdns_eventloop_callback write_cb;
        getdns_eventloop_callback timeout_cb;

        /* Pointer to the underlying event */
        void *ev;
} getdns_eventloop_event;
```

Appendix – Custom memory functions

```
getdns_return_t
getdns_context_create_with_extended_memory_functions(
    getdns_context **context,
    int set_from_os,
    void *userarg,
    void *(*malloc) (void *userarg, size_t),
    void *(*realloc)(void *userarg, void *, size_t),
    void  (*free)   (void *userarg, void *)
);
```

Appendix – DANE validation in OpenSSL

```
if (!(ext = getdns_dict_create()))                                   ; /* error */
else if ((r = getdns_dict_set_int( ext
                                 , "dnssec_return_only_secure"
                                 , GETDNS_EXTENSION_TRUE )))         ; /* error */
else if ((r = getdns_general_sync( gctx
                                 , "_443._tcp.getdnsapi.net"
                                 , GETDNS_RRTYPE_TLSA, ext, &resp))) ; /* error */
else if ((r = getdns_dict_get_int(resp,
     "/replies_tree/0/answer/0/rdata/certificate_usage", &usage)))   ; /* error */
else if ((r = getdns_dict_get_int(resp,
     "/replies_tree/0/answer/0/rdata/selector", &selector)))         ; /* error */
else if ((r = getdns_dict_get_int(resp,
     "/replies_tree/0/answer/0/rdata/matching_type", &mtype)))       ; /* error */
else if ((r = getdns_dict_get_int(resp,
     "/replies_tree/0/answer/0/rdata/certificate_association_data", &ca_data)))
        ; /* handle error */
else if (!(sctx = SSL_CTX_new(TLS_client_method())))                 ; /* error */
else if (SSL_CTX_dane_enable(sctx) <= 0)                             ; /* error */
else if ((ssl = SSL_new(sctx)) == NULL)                              ; /* error */
else if (SSL_dane_enable(ssl, "getdnsapi.net") <= 0)                 ; /* error */
else if (SSL_dane_tlsa_add(ssl, usage, selector, mtype, ca_data->data, ca_data->size))
        /* handle error */
```