DNS Privacy

EDU Tutorial

dnsprivacy.org

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IETF 99

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Overview

- **The problem:** Why Internet privacy and DNS Privacy are important (DNS leakage)
- **Recent Progress:** Chart progress during last 3-4 years (DPRIVE)
- **Where are we now?** Present current status and tools

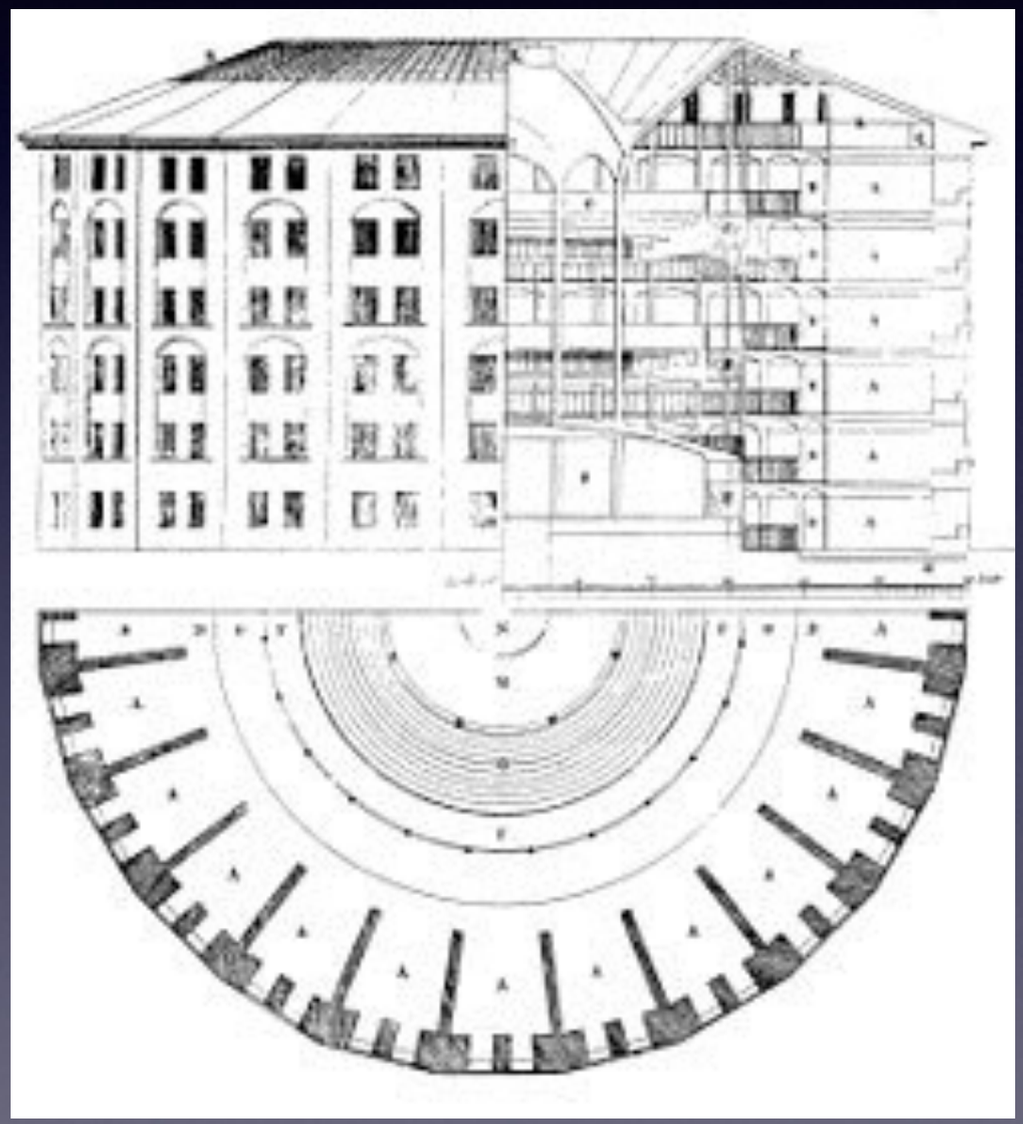
Internet Privacy

Slides from: Daniel Kahn Gillmor (ACLU)

Why does internet privacy matter?

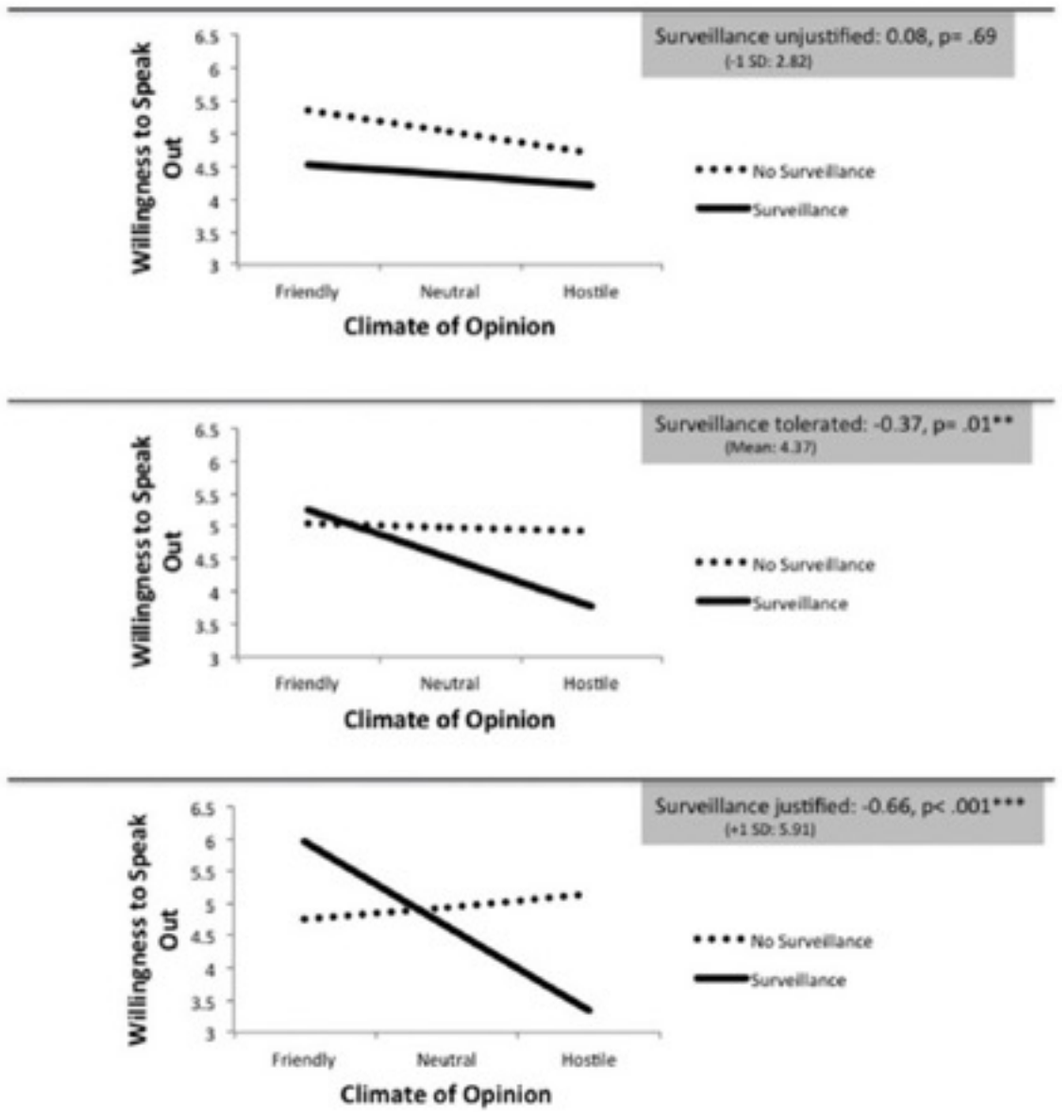
- Surveillance as social control

- Machine learning at scale today means small number of people controlling network can perform mass surveillance



Behaviour changes

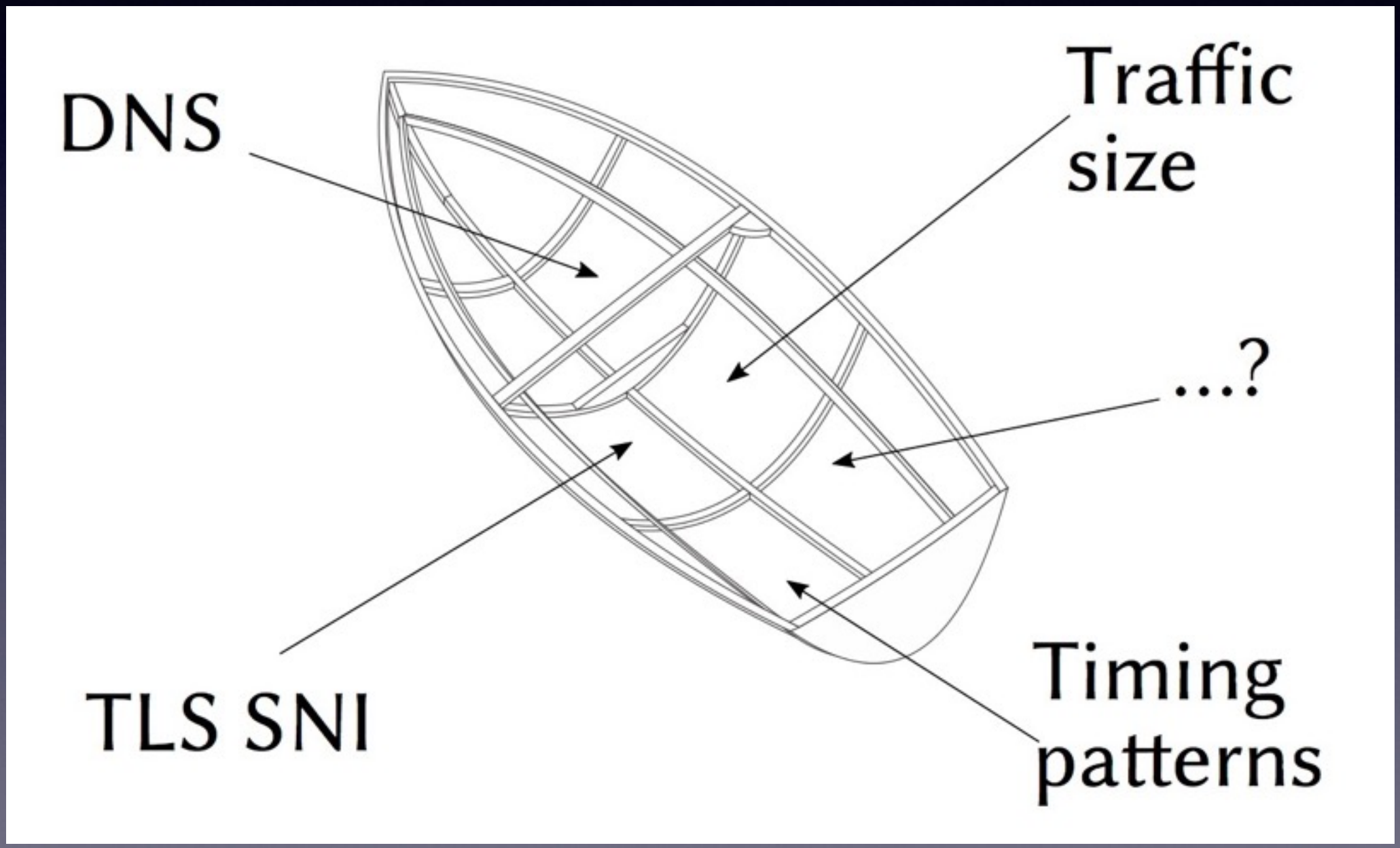
(even when no-one is watching)



Under Surveillance:
Examining Facebook's Spiral of Silence Effects in the Wake of NSA Internet Monitoring

Elizabeth Stoycheff,
Journalism & Mass Communication Quarterly 1-16

DNS is part of the leaky boat problem



DNS Privacy

- A brief history

IETF Privacy activity

March 2011	**I-D:** Privacy Considerations for Internet Protocols (IAB)
June 2013	 Snowdon revelations What timing!
July 2013	**RFC6973:** Privacy Considerations for Internet Protocols
May 2014	**RFC7258**: Pervasive Monitoring is an Attack: "**PM is an attack on the privacy of Internet users and organisations**."

RFC 7258

“**PM is an attack on the privacy of Internet users and organisations**.”

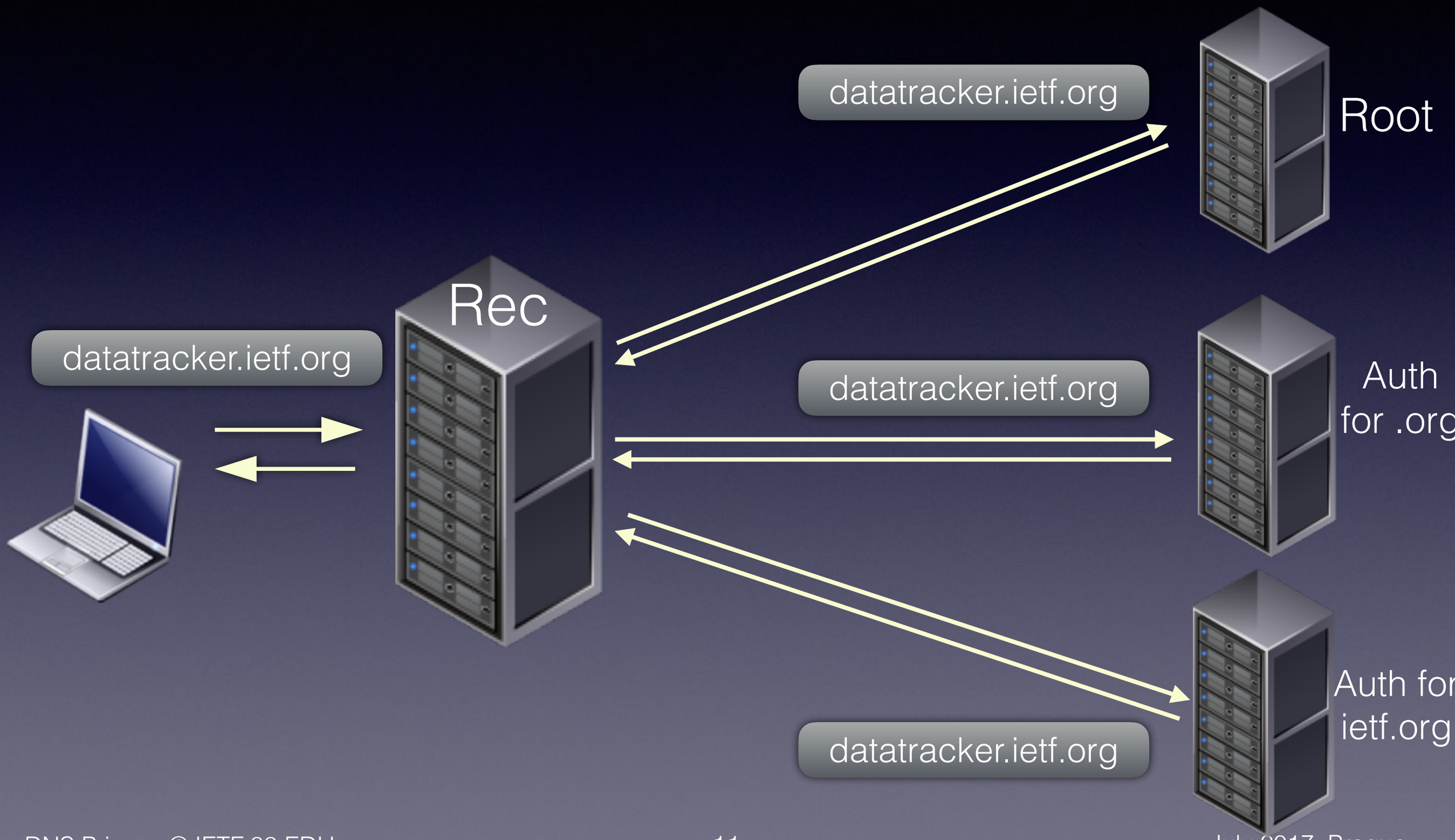
“…that needs to be **mitigated** where possible, **via the design of protocols** that make PM significantly more expensive or infeasible**.** “

DNS Privacy in 2013?

- DNS is 30 year old! [RFC1034/5 (1987)]
  - Original design availability, redundancy and speed!
  - DNS is an ‘enabler’
- DNS standards:
  - UDP (99% of traffic to root)
  - TCP only for ‘fallback’ (pre 2010)
- Perception: The DNS is public, right? It is not sensitive/personal information….it doesn’t need to be protected/encrypted

DNS sent in clear text
-> NSA: ‘**MORECOWBELL**’

DNS Disclosure Example 1



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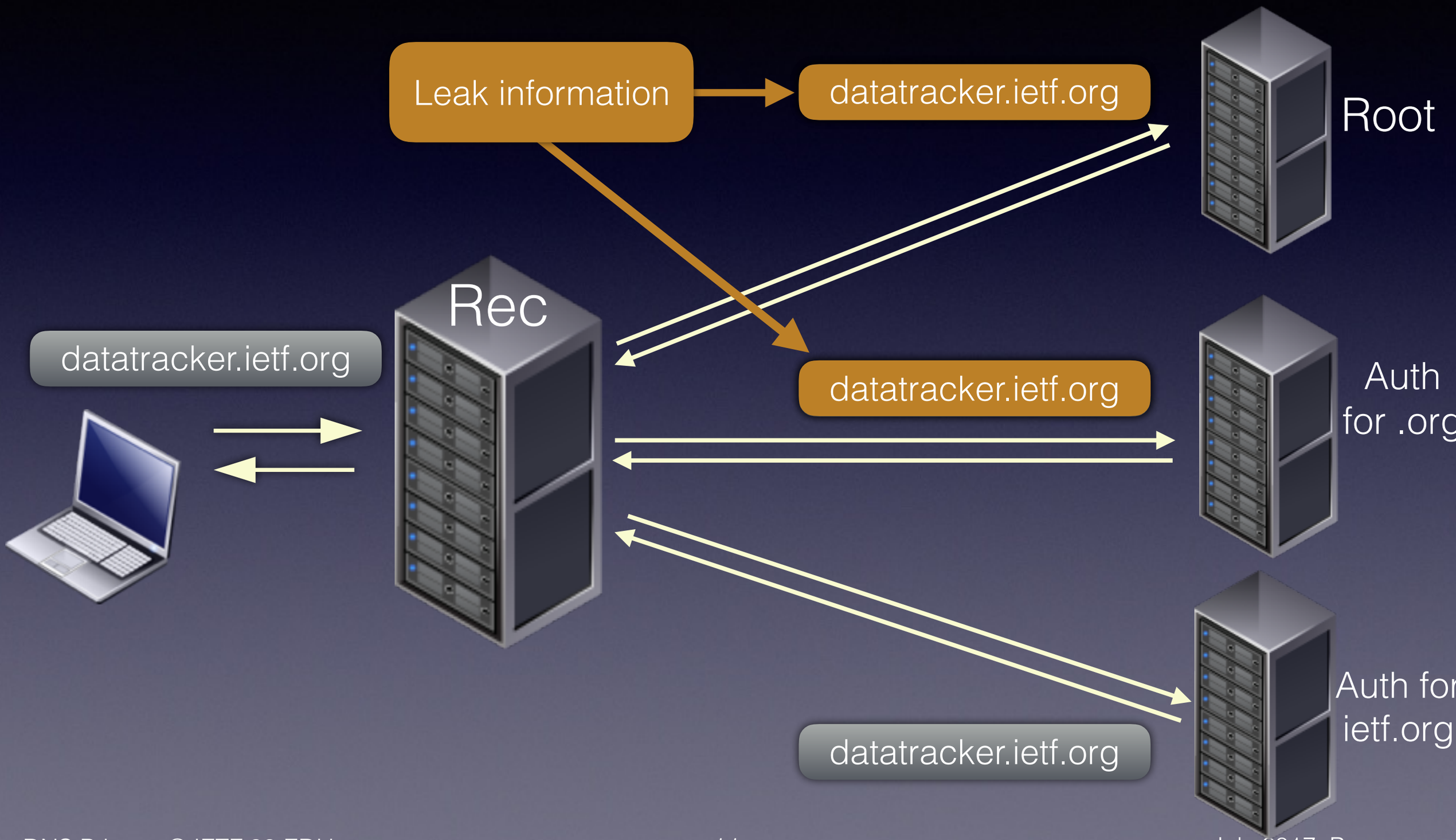

EDNS0 problem

- **RFC6891**: Extension Mechanisms for DNS (EDNS0)

Intended to enhance DNS protocol capabilities

- But…. mechanism enabled addition of **end-user data into** DNS queries (non-standard options)

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ISP justification: Parental Filtering (per user)

CDN justification: Faster content (geo location)

DNS Disclosure Example 2

Parental Filtering

ietf.org ?
[00:00:53:00:53:00]

Stub

CPE

Rec

Auth

[User src address]
MAC address or id
in DNS query

DNS Disclosure Example 2

Parental Filtering

CDN Geo-location

ietf.org ?
[00:00:53:00:53:00]

? ietf.org ?
[192.168.1]

Stub

Rec

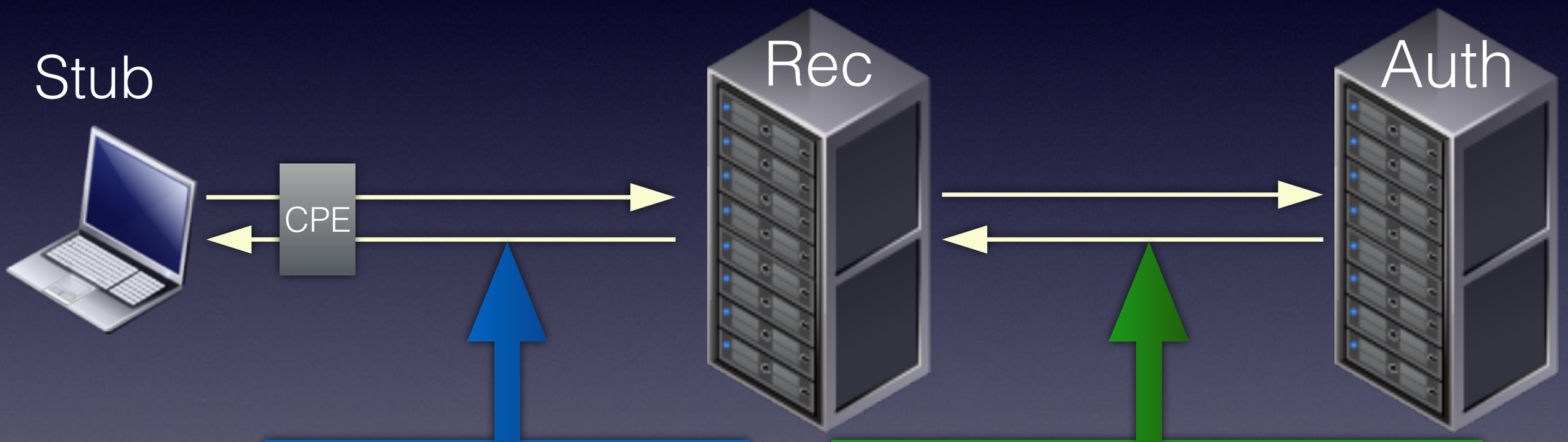
Auth

CPE

[User src address]
MAC address or id
in DNS query

Client Subnet (RFC7871)
contains source subnet
in DNS query

DNS Disclosure Example 2



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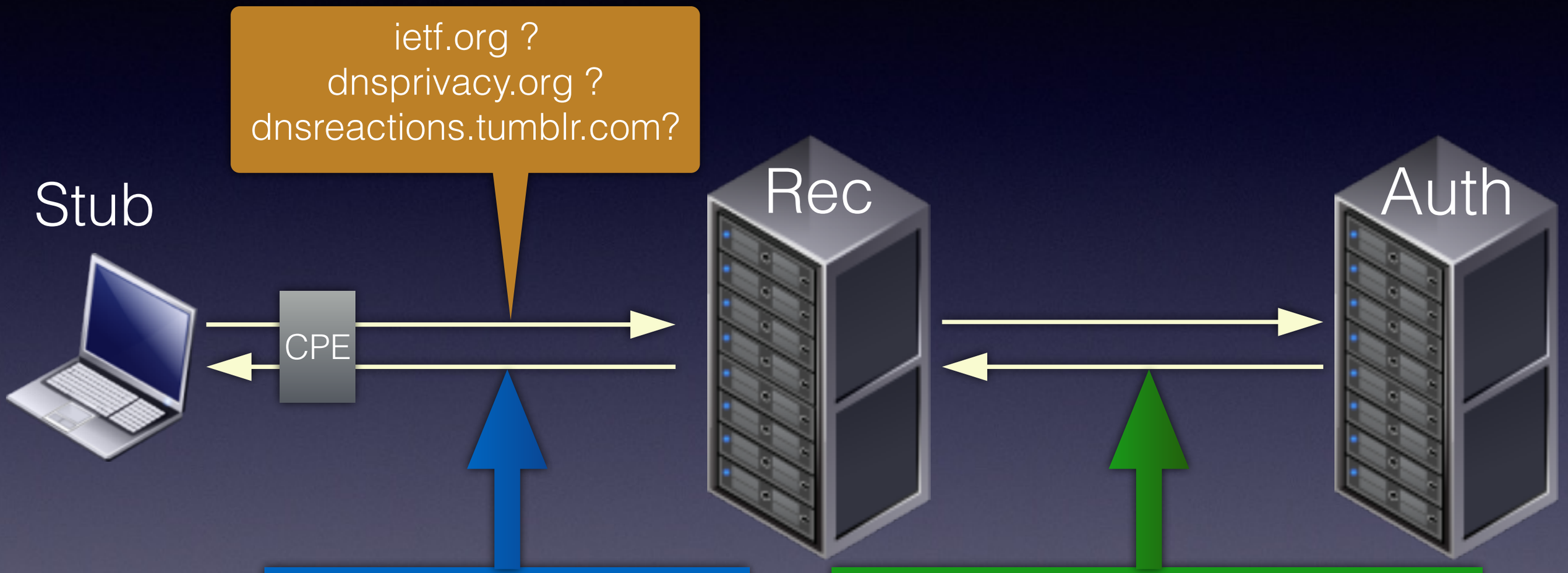

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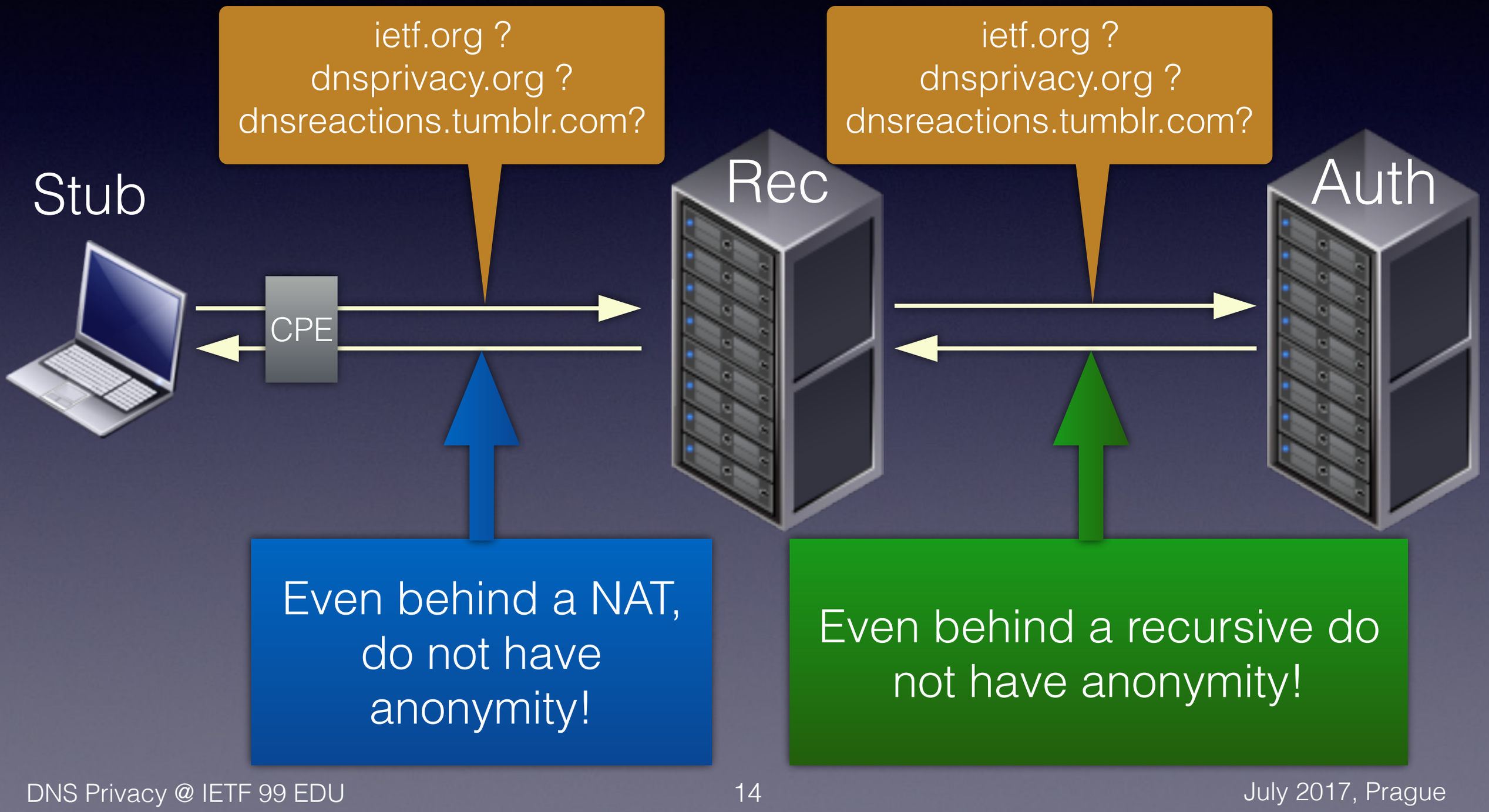

DNS: It’s not just for names

Almost every activity starts with a DNS query (try it)!

- MX records (email domain)
- SRV records (services)
- OPENPGPKEY (email addresses)
- …this is only going to increase….

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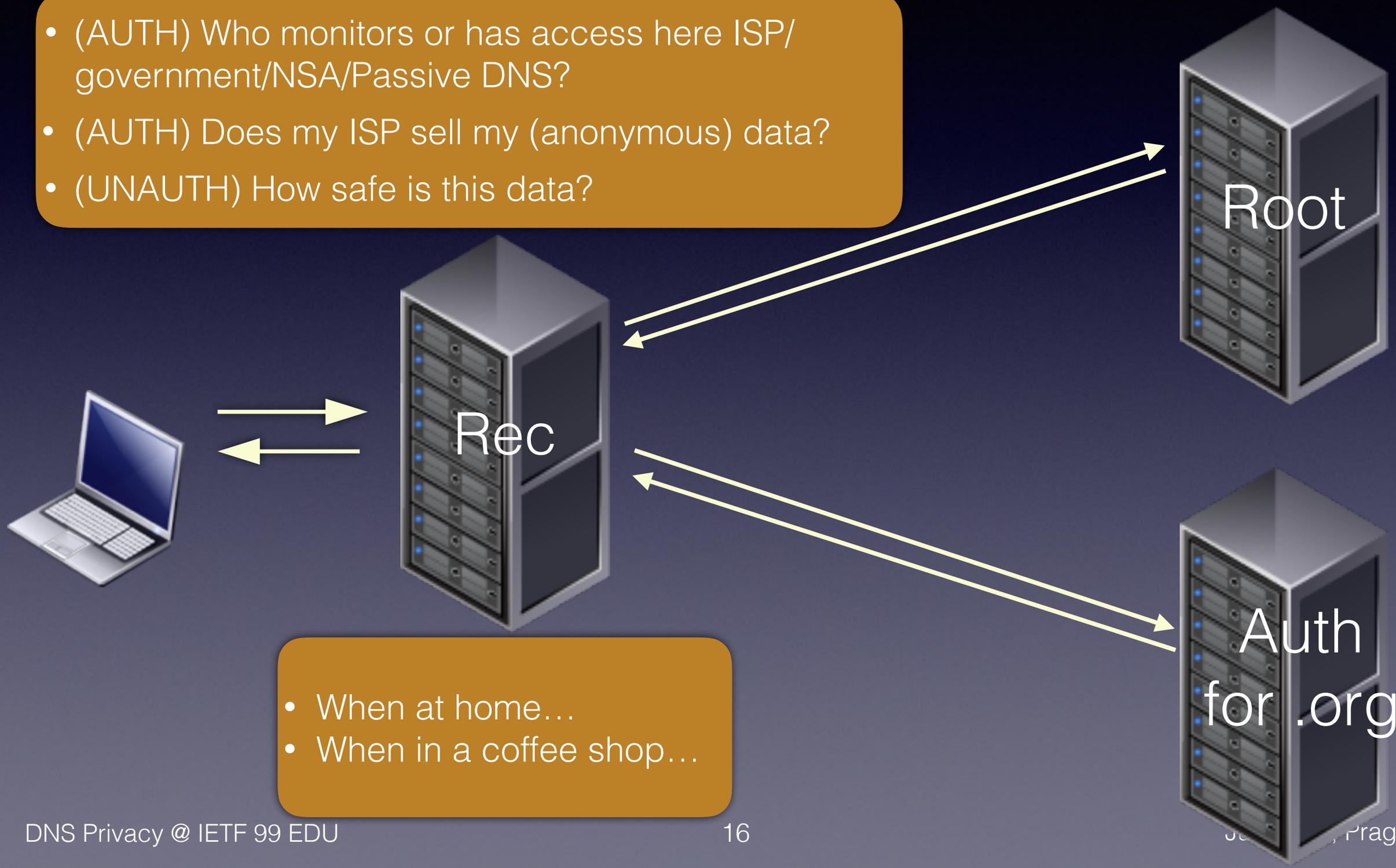
DNS Disclosure Example 3

- (AUTH) Who monitors or has access here ISP/ government/NSA/Passive DNS?
- (AUTH) Does my ISP sell my (anonymous) data?
- (UNAUTH) How safe is this data?



- When at home…
- When in a coffee shop…

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Who monitors or has access here?

DNS - leakage

- Basic problem is leakage of meta data
  - Allows fingerprinting and re-identification of individuals
  - Even without user meta data traffic analysis is possible based just on timings and cache snooping
  - Operators see (and log) your DNS queries

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DNS Risk Matrix

	In-Flight		At Rest	
Risk	**Stub => Rec**	**Rec => Auth**	**At Recursive**	**At Authoritative**
Passive Monitoring	●	●		
Active Monitoring	●	●		
Other Disclosure Risks e.g. Data breaches			●	●

DNS Privacy options (2013)

- DNSCurve

  Recursive-Auth

  - Daniel J. Bernstein, initial interest but not adoption
- DNSCrypt

  Stub-Recursive

  - Several clients and open DNSCrypt Resolvers (OpenDNS), [Yandex browser]

    Anti-spoofing, anti DoS
- (2014) Unbound did DNS-over-TLS for DNSSEC-Trigger
- Goals were for **authentication/DNSSEC** with some privacy, documented but not standard

DPRIVE WG et al.

DPRIVE WG

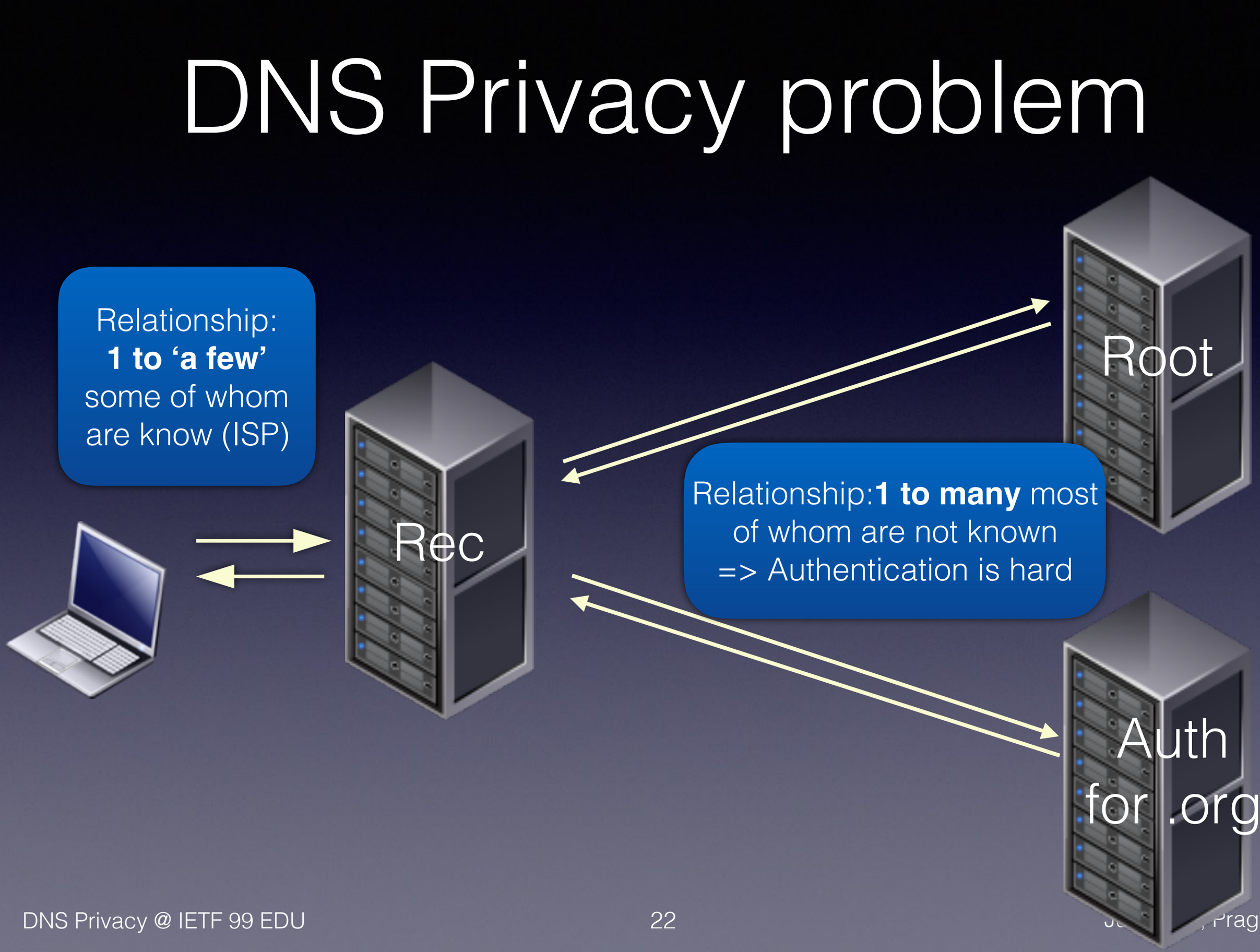
- DPRIVE WG create in 2014

Charter: Primary Focus is
Stub to recursive

- **Why not tackle whole problem?**
  - Don't boil the ocean, stepwise solution
  - Stub to Rec reveals most information
  - Rec to Auth is a particularly hard problem

DNS Privacy problem

Relationship:
1 to 'a few'
some of whom
are know (ISP)



Relationship:**1 to many** most
of whom are not known
=> Authentication is hard

Problem statement: RFC 7626

DNS Privacy Considerations:
Expert coverage of risks throughout DNS ecosystem

- **Rebuts “alleged public nature of DNS data”**
  - The **data** may be public, but a DNS ‘**transaction**’ is not/should not be.

“A typical example from outside the DNS world is: the web site of Alcoholics Anonymous is public; the fact that you visit it should not be.”

Stub/Rec Encryption Options

	Pros	Cons
STARTTLS	• Port 53 • Known technique • Incrementation deployment	• Downgrade attack on negotiation • Port 53 - middleboxes blocking? • Latency from negotiation
TLS (new port)	• New DNS port (no interference with port 53) • Existing implementations	• New port assignment • Scalability?
DTLS (new port)	• UDP based • Not as widely used/ deployed	• Truncation of DNS messages (just like UDP) ➡️Fallback to TLS or clear text ❌Can't be standalone solution

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Encrypted DNS ‘TODO’ list

1. Get a new port
2. DNS-over-TCP/TLS: Address issues in standards and implementations
3. Tackle authentication of DNS servers (bootstrap problem)
4. What about traffic analysis of encrypted traffic - msg size & timing still tell a lot!

1.Get a new port!

- One does not simply get a new port…
- Oct 2015 - **853** is the magic number

Your request has been processed. We have assigned the following system port number as an early allocations per RFC7120, with the DPRIVE Chairs as the point of contact:

domain-s	853	tcp	DNS query-response protocol run over TLS/DTLS
domain-s	853	udp	DNS query-response protocol run over TLS/DTLS

2. DNS + TCP/TLS?

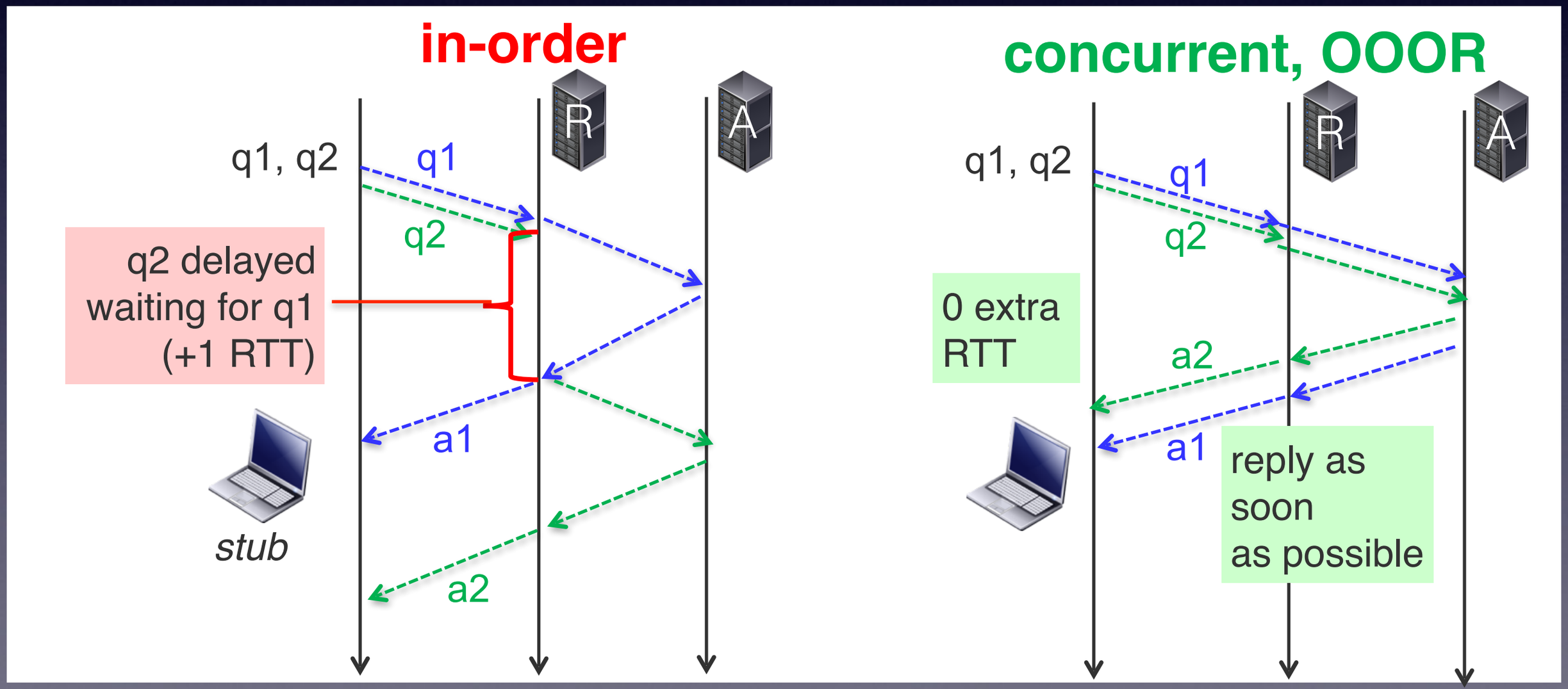
- DNS-over-TCP history:
  - Typical DNS clients do ‘one-shot’ TCP
  - Performance tools based on one-shot TCP
  - DNS servers have **very** basic TCP capabilities
  - No attention paid to TCP tuning, robustness

2. Fix DNS-over-TCP/TLS

Goal	How?
Optimise set up & resumption	**RFC7413**: TFO Fast Open **RFC5077**: TLS session resumption **TLS 1.3** (0-RTT)
Amortise cost of TCP/TLS setup	**RFC7766** (bis of RFC5966) - March 2016: Client pipelining (not one-shot!), Server concurrent processing, Out-of-order responses **RFC7828:** Persistent connections (Keepalive)
Servers handle many connections robustly	Learn from HTTP world!

Performance (RFC7766)

AIM: Performance on a par with UDP



3. Authentication in DNS-over-(D)TLS

2 Usage Profiles:

- Strict
  - “Do or do not. There is no try.”
- Opportunistic
  - “Success is stumbling from failure to failure with no loss of enthusiasm”

3. Authentication in DNS-over-(D)TLS

2 Usage Profiles:

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3. Authentication in DNS-over-(D)TLS

2 Usage Profiles:

- Strict → (Encrypt & Authenticate) or Nothing
  - "Do or do not. There is no try."
- Opportunistic → Try in order:
  1. Encrypt & Authenticate then
  2. Encrypt then
  3. Clear text
  - "Success is stumbling from failure to failure with no loss of enthusiasm"

3. Authentication in DNS-over-(D)TLS

- Authentication based on config of either:
    - Authentication domain name (easier)
    - SPKI pinset (harder)
- Shouldn’t DNS use DANE…? Well - even better:
    - I-D: TLS DNSSEC Chain Extension

DNS Auth using DANE

DNS Privacy client [DNSSEC]

DNS Privacy server

1: Obtain a Auth Domain name & IP address

(1a)
- Configure Auth domain name
- Do Opportunistic A lookup

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2a:
- Opportunistic lookup of DANE records for server
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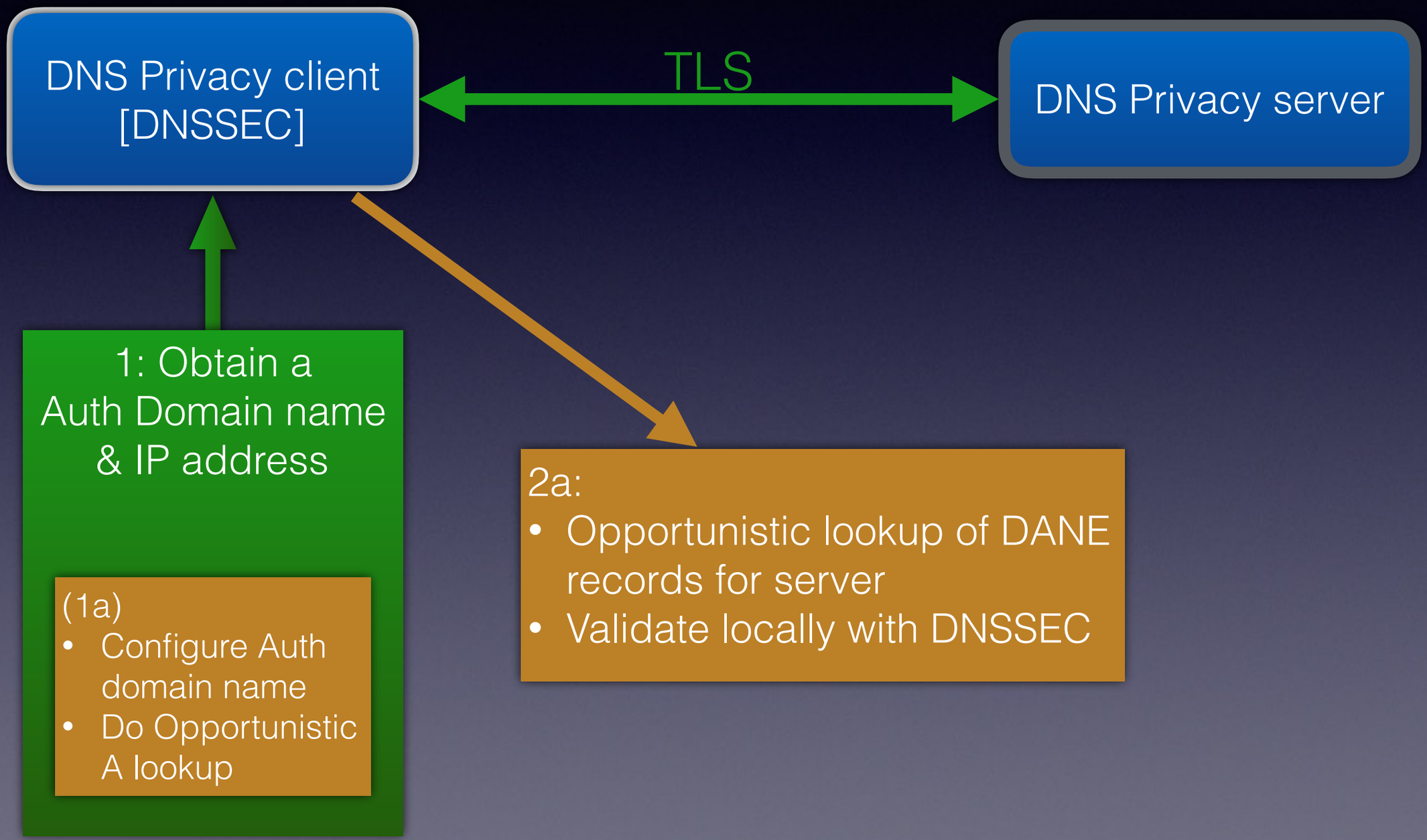

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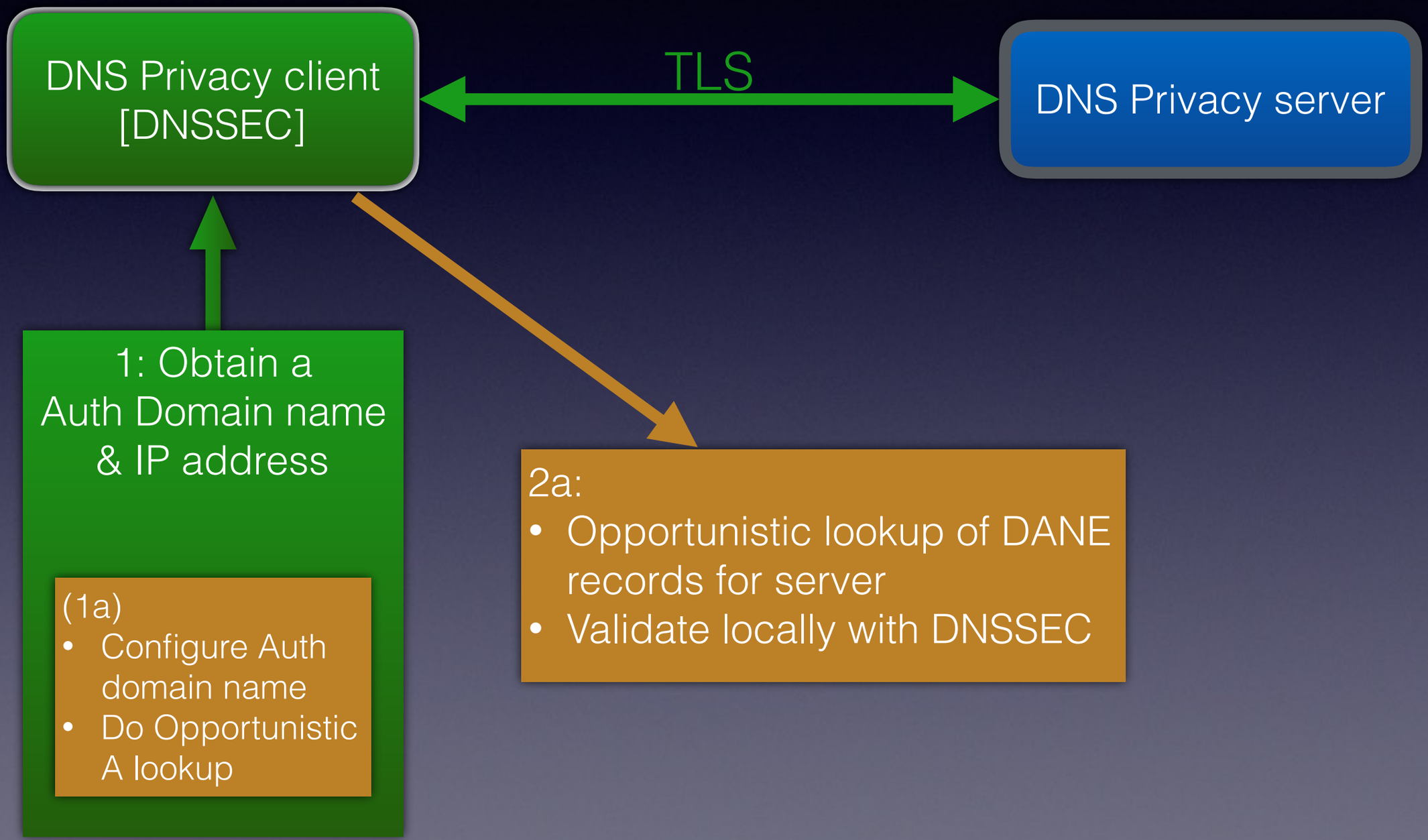

TLS DNSSEC Chain Extension

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TLS DNSSEC Chain Extension

DNS Privacy client [DNSSEC]

1: Obtain a Auth Domain name & IP address

(1a)
- Configure Auth domain name
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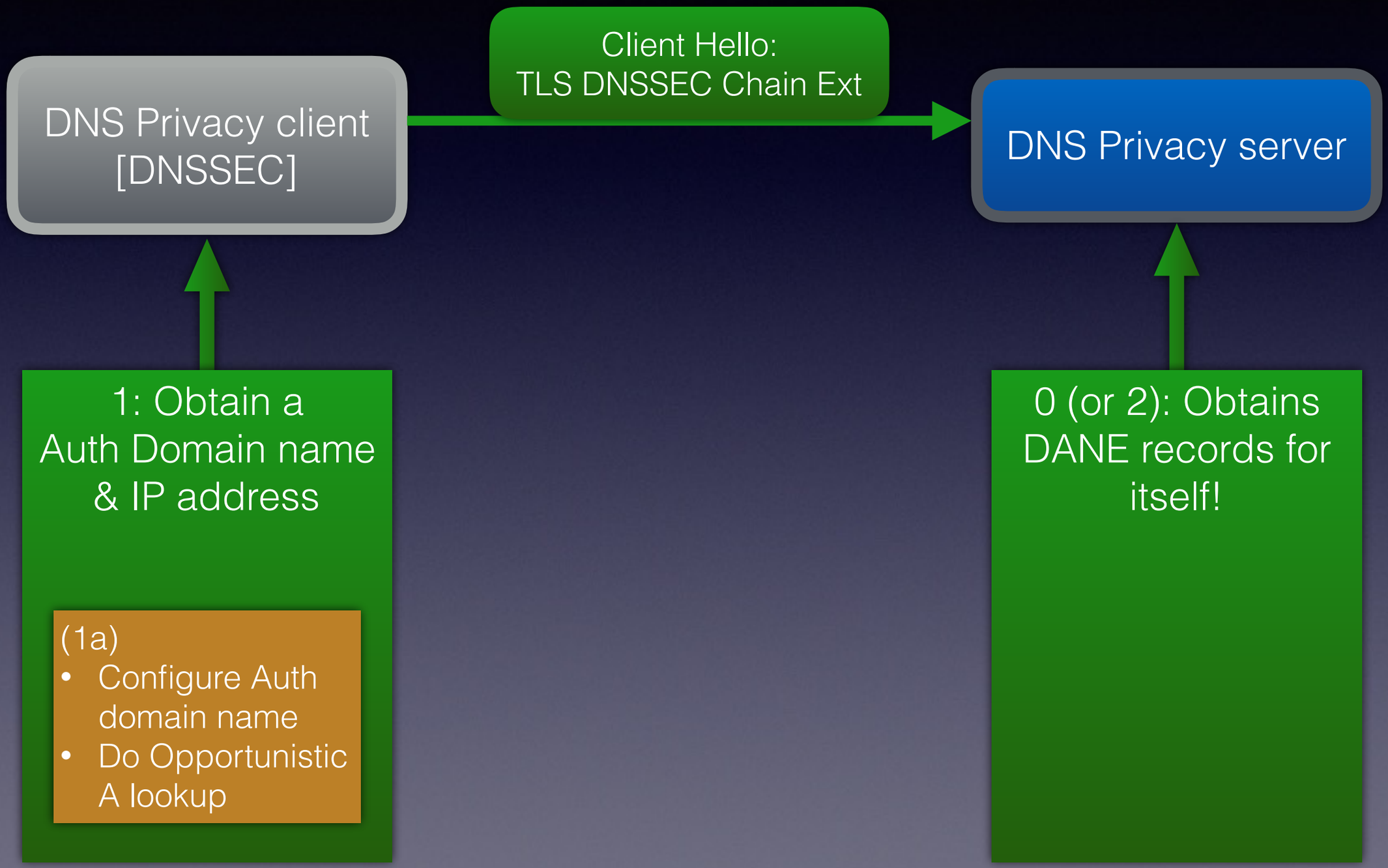
DNS Privacy server

0 (or 2): Obtains DANE records for itself!

TLS DNSSEC Chain Extension



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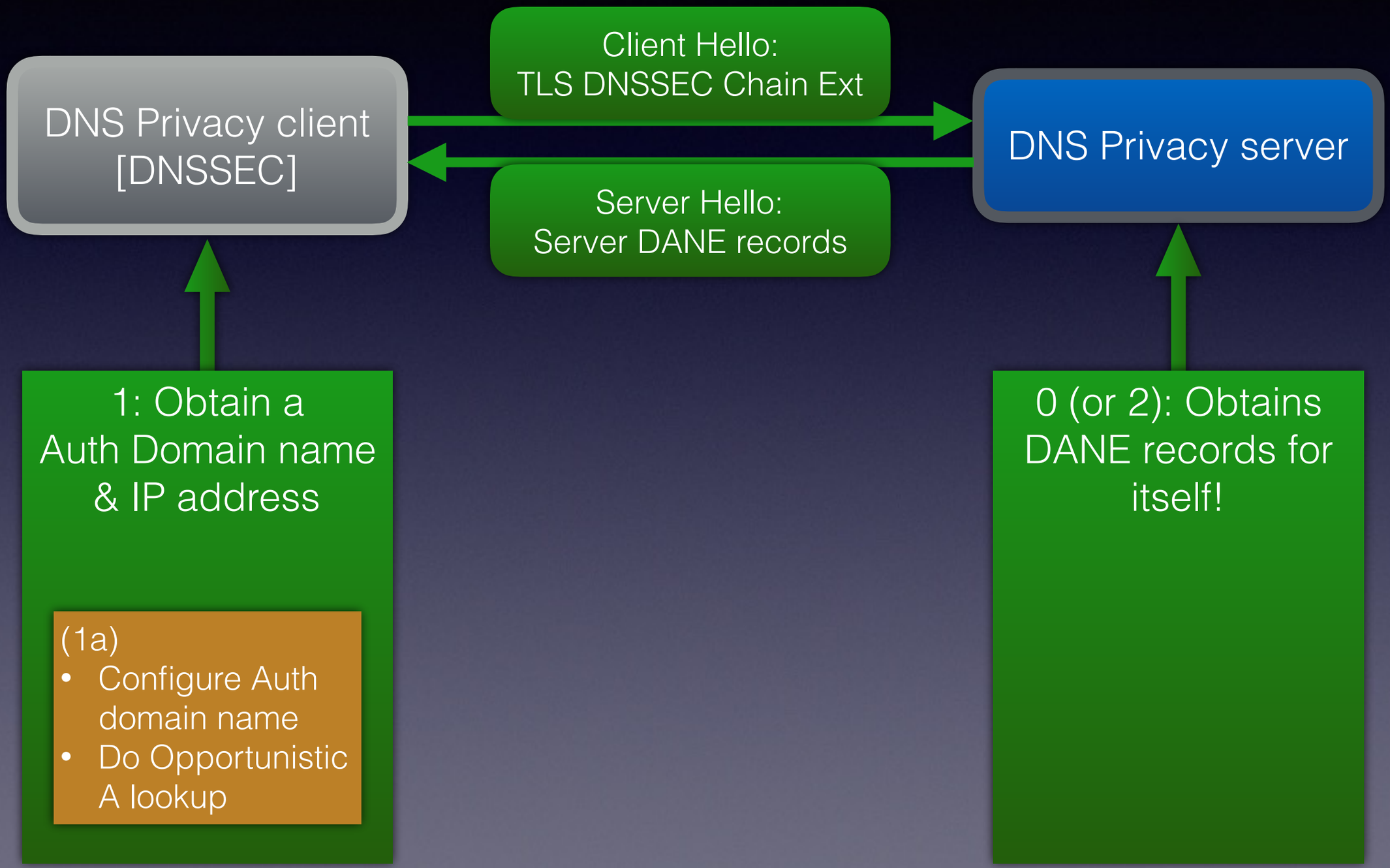

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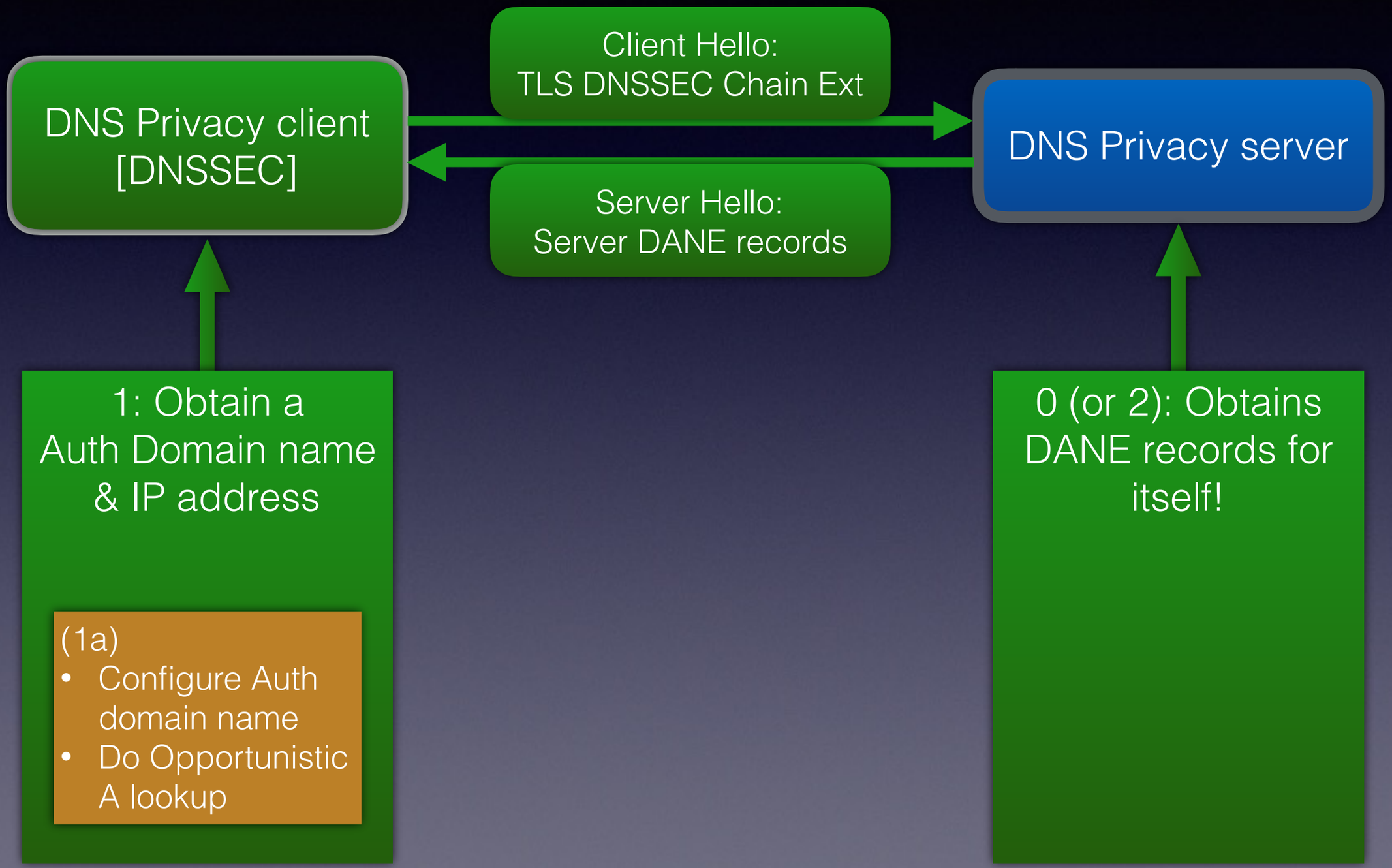

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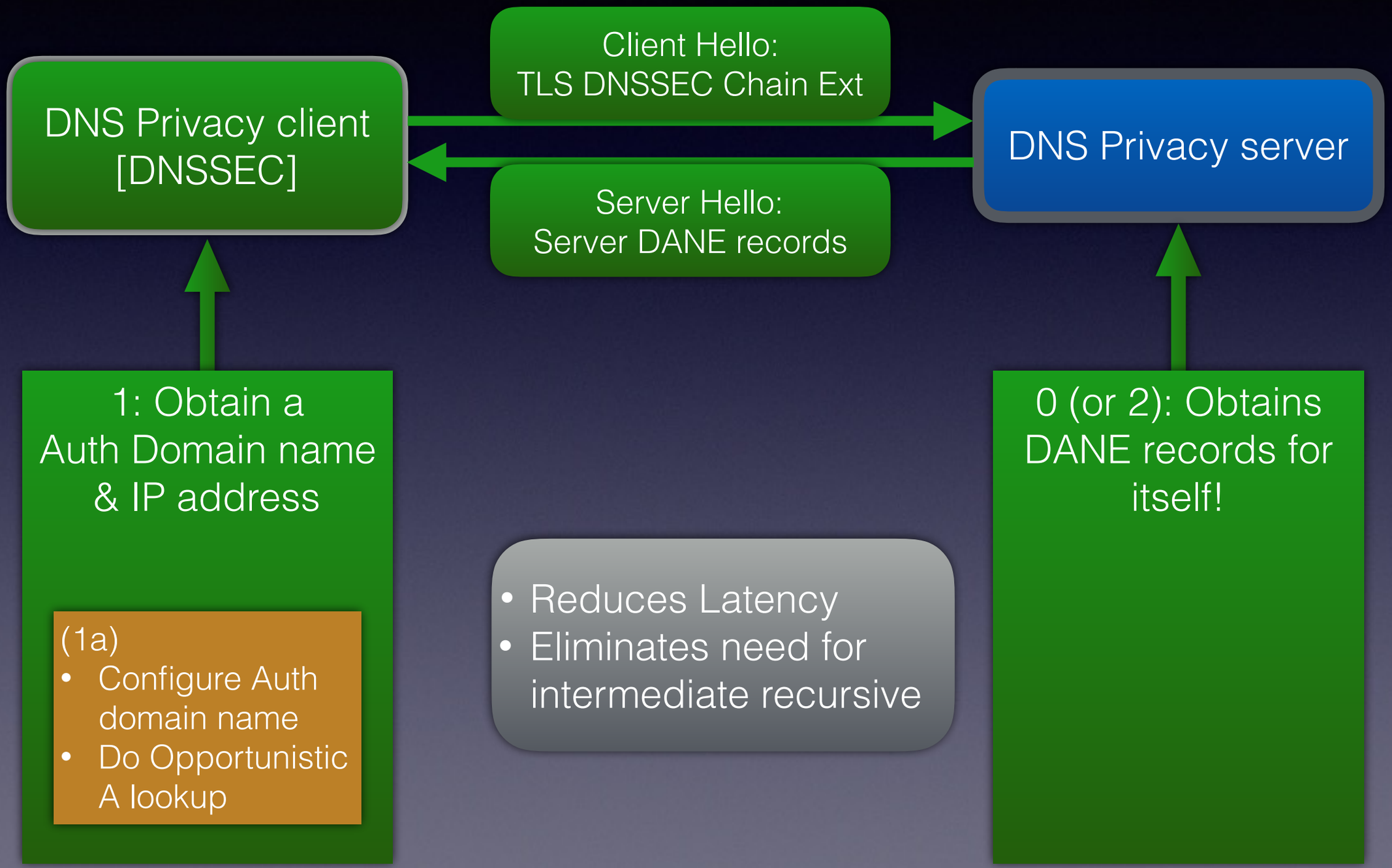


DPRIVE Solution Documents
(stub to recursive)

Document	Date	Topic
RFC7858	May 2016	DNS-over-TLS
RFC7830	May 2016	**4. EDNS0 Padding Option**
RFC8094	Feb 2017	DNS-over-DTLS
draft-ietf-dprive-dtls-and-tls-profiles	IESG LC	Authentication for DNS-over-(D)TLS

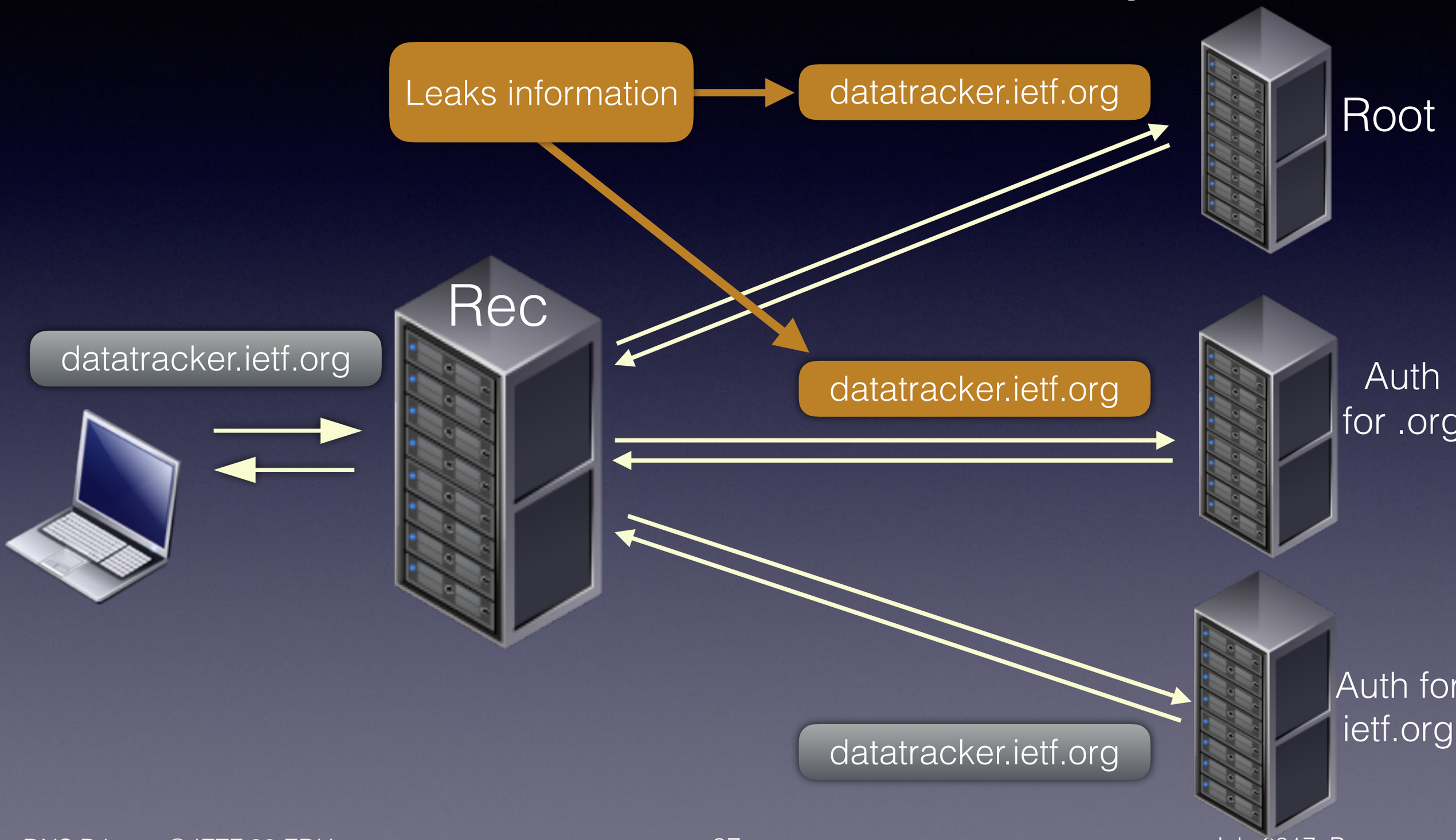
*Category: Experimental

What about Recursive to Authoritative?

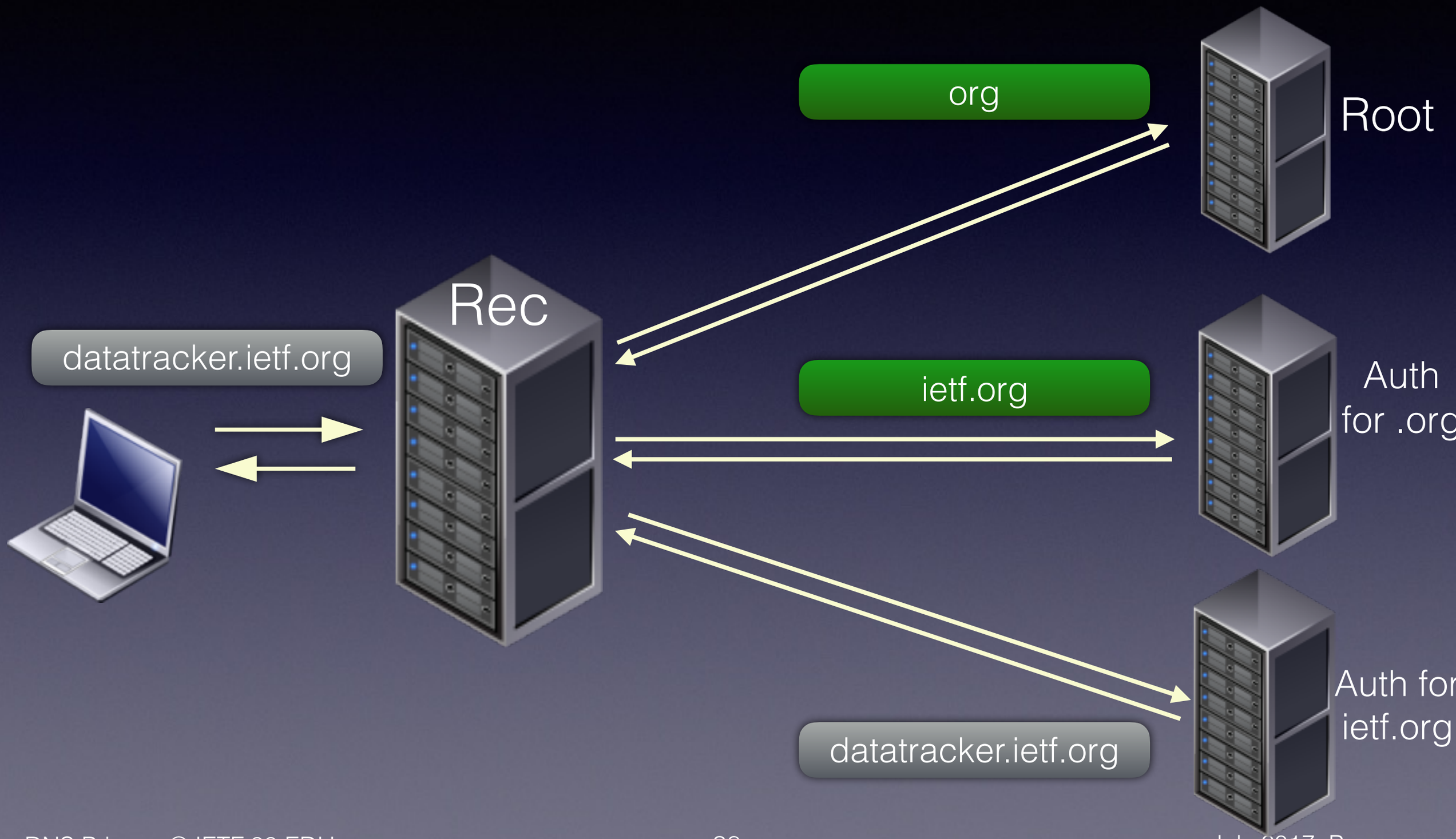
- I-D: Next step for DPRIVE: resolver-to-auth link
  - Presents 6 authentication options
- DPRIVE - Re-charter…
- Data on DNS-over-(D)TLS

Other work….

DNS Disclosure Example 1



RFC7816: QNAME Minimisation



DNS-over-HTTP(S)

Avoids e.g. port 853 blocking

- Google: DNS-over-HTTPS (non-standard)
- Standards are in flux (many drafts….)
  - DNS wire-format over HTTP (tunnelling)
  - DNS over HTTPS (query origination)

Implementations exist

Mix HTTPS/2 and DNS on one connection

DNS-over-QUIC

- DNS over dedicated QUIC connections
    - QUIC is a developing open source protocol (from Google) that runs over UDP (HTTPS/2-like)
    - **~35% of Google's egress traffic**
      (~7% of Internet traffic)
    - **Reliable**, low latency, performant
    - Source address validation, no MTU limit
    - **Encrypted**

DNS Data handling

- Do you read the small print of your ISPs contract?
- More work/research needed in this area
- **Monitoring** of government policy and practice
- **Transparency** from providers on policy and breaches
- Methods for **de-identification** of user data (e.g. DITL)
- '**PassiveDNS**' data used for research/security

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Not always a technical solution: Needs more work

Risk Mitigation Matrix

	In-Flight		At Rest	
Risk	**Stub => Rec**	**Rec => Auth**	**At Recursive**	**At Authoritative**
Passive monitoring	**Encryption (e.g. TLS, HTTPS)**	**QNAME Minimization**		
Active monitoring	**Authentication & Encryption**			
Other Disclosure Risks e.g. Data breaches			**Data Best Practices (Policies) e.g. De-identification**	

DNS Service Discovery

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- Devices advertise services on network (DNS, mDNS) - leakage can be global
- Other devices then discover the service and use it

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Alice's Images	. _imageStore._tcp	. local
Alice's Mobile Phone	. _presence._tcp	. local
Alice's Notebook	. _presence._tcp	. local

DNS-SD Privacy

- Advertising leaks information about:
  - User - ‘name’, devices, services (user tracking)
    - Devices - services & attributes (port, priorities)
      - Device fingerprinting possible

=> Software or specific device identification

- Discovery leaks info about preferred services

DNS-SD WG

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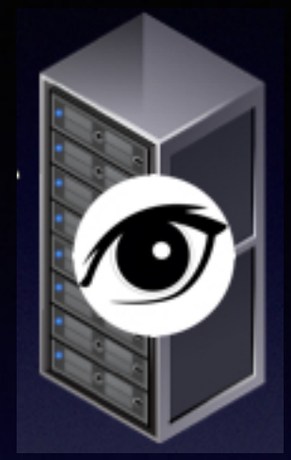
DNS Privacy Implementation Status

dnsprivacy.org



- DNS Privacy Project homepage
- **Who?** Sinodun, NLnet Labs, Salesforce,…
  (plus various grants and individual contributions)
- **What?** Point of reference for DNS Privacy services
  - Quick start guides for operators & end users
  - Ongoing work - presentations, IETF, Hackathons
  - Tracking of DNS-over-TLS experimental servers

RECURSIVE

Recursive implementations

Features		Recursive resolver		
		Knot Res	Unbound	BIND
TCP/TLS Features	TCP fast open			
	Process pipelined queries			
	Provide OOOR			
	EDNS0 Keepalive			
TLS Features	TLS on port 853			
	Provide server certificate			
	EDNS0 Padding			
Rec => Auth	QNAME Minimisation			

- Dark Green: Latest stable release supports this
- Light Green: Patch available
- Yellow: Patch/work in progress, or requires building a patched dependency
- Purple: Workaround available
- Grey: Not applicable or not yet planned

RECURSIVE

Alternative server side solutions

- Pure TLS load balancer
  - NGINX, HAProxy
  - BIND article on using stunnel

Disadvantages
- DNS specific access control is missing
- pass through of edns0-tcp-keepalive option

- dnsdist from PowerDNS would be great…
  - But no support yet but requested: #3980

STUB

Stub implementations

Features		Stub			
		getdns (stubby)	kdig	BIND (dig)	ldns
TCP/TLS Features	TCP fast open				
	Connection reuse				
	Pipelining of queries				
	Process OOOR				
	EDNS0 Keepalive				
TLS Features	TLS on port 853				
	Authentication of server				
	EDNS0 Padding				

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Implementation Status Summary

- Increasing uptake of better DNS-over-TCP, QNAME minimisation
- Several implementations of DNS-over-TLS
- None yet of DNS-over-DTLS
- BII has DNS-over-HTTP implementation

DNS Privacy Deployment Status

RECURSIVE

Experimental!

DNS-over-TLS Servers

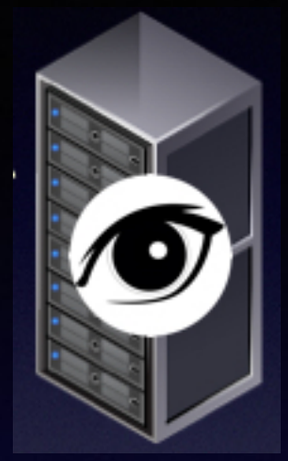
Hosted by	Notes
NLnet Labs	Unbound
Surfnet (Sinodun)	BIND + HAProxy BIND + nginx
UncensoredDNS	Unbound
dns.cmrg.net	Knot Resolver

12 at last count - find details at: DNS Test Servers

RECURSIVE

Experimental!

Server monitoring



Project dnsprivacy-monitoring

* Green indicates success

* Red indicates failed test (this might result from non DNS related issues such server being off line, blocking from the probe location, etc.) Note that the 'Strict mode' tests could fail for a number of reasons including incorrect credentials, self-signed certificates for name only authentication, incompatible TLS version or Cipher suites, etc. The console log of the test may give more information.

* Grey indicates test not run (e.g. due to lack of available transport or the lack of the SPKI pin)

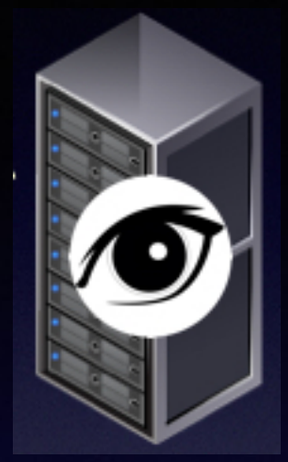
Authentication information is taken from https://dnsprivacy.org/wiki/display/DP/DNS+Privacy+Test+Servers
These tests use Stephane Bortzmeyer's nagios plugin - see https://github.com/bortzmeyer/monitor-dns-over-tls

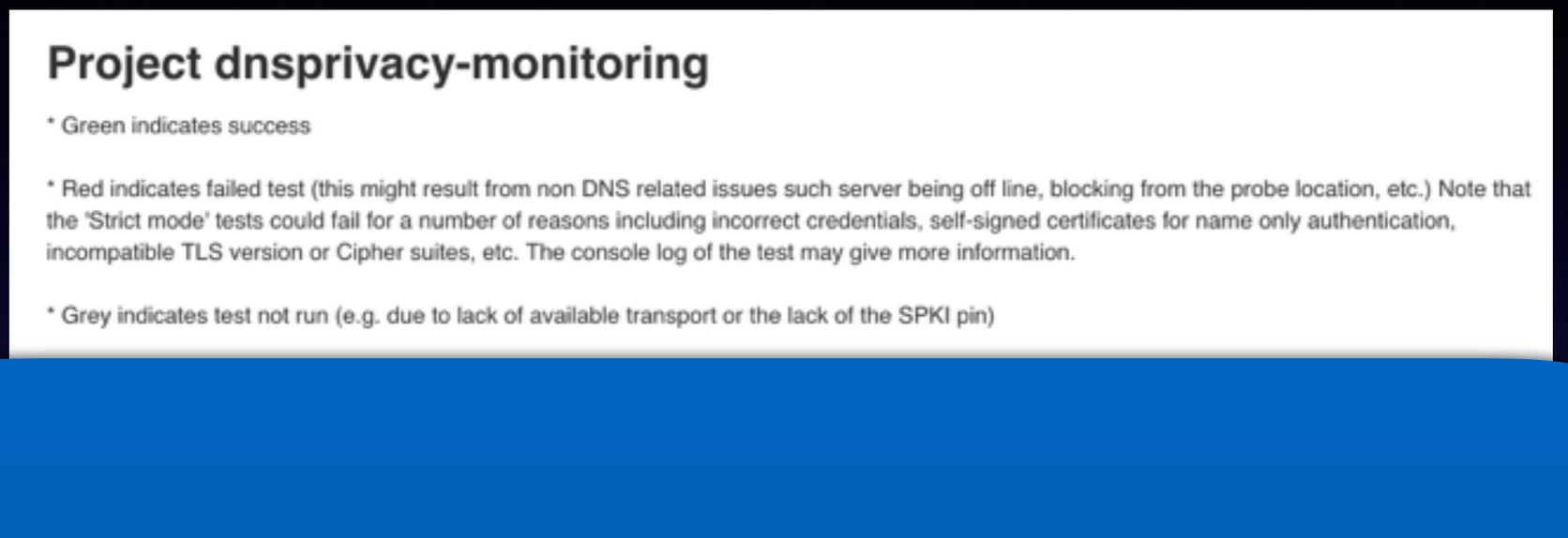
Configuration Matrix		Responds over TLS	Strict mode - Name only	Strict mode - SPKI only	Certificate expiry > 0 days	Certificate expiry > 14 days	QNAME minimisation used
getdnsapi.net	v6	✓	✓	✓	✓	✓	✓
	v4	✓	✓	✓	✓	✓	✓
dnsovertls.sinodun.com	v6	✓	✓	✓	✓	✓	!
	v4	✓	✓	✓	✓	✓	!
dnsovertls1.sinodun.com	v6	✓	✓	✓	✓	✓	!
	v4	✓	✓	✓	✓	✓	!
dns.cmrg.net	v6	✓	✓	✓	✓	✓	✓
	v4	✓	✓	✓	✓	✓	!
tls-dns-u.odvr.dns-oarc.net	v6	✓	!	!	✓	✓	!
	v4	✓	!	!	✓	✓	!
dns-resolver.yeti.eu.org	v6	✓	✓	✓	✓	✓	✓
	v4	●	●	●	●	●	●
yeti-rr.datev.net	v6	✓	✓	✓	✓	✓	✓
	v4	●	●	●	●	●	●
unicast.censurfridns.dk	v6	✓	✓	●	✓	✓	!
	v4	✓	✓	●	✓	✓	!
dns-tls.openbsd.se	v6	●	●	●	●	●	●
	v4	✓	✓	✓	✓	✓	!

RECURSIVE

Experimental!

Server monitoring





IETF NOC is running 2 experimental DNS-over-TLS servers at IETF 99!

Check to meeting network information page!

CLIENTS

Stubby

- A privacy enabling stub resolver: User Guide
- Available in getdns (1.1.1 release)
  - Run as daemon handling requests
  - Configure OS DNS resolution to point at *localhost*
  - DNS queries then proxied over TLS
  - Comes with config for experimental servers

CLIENTS

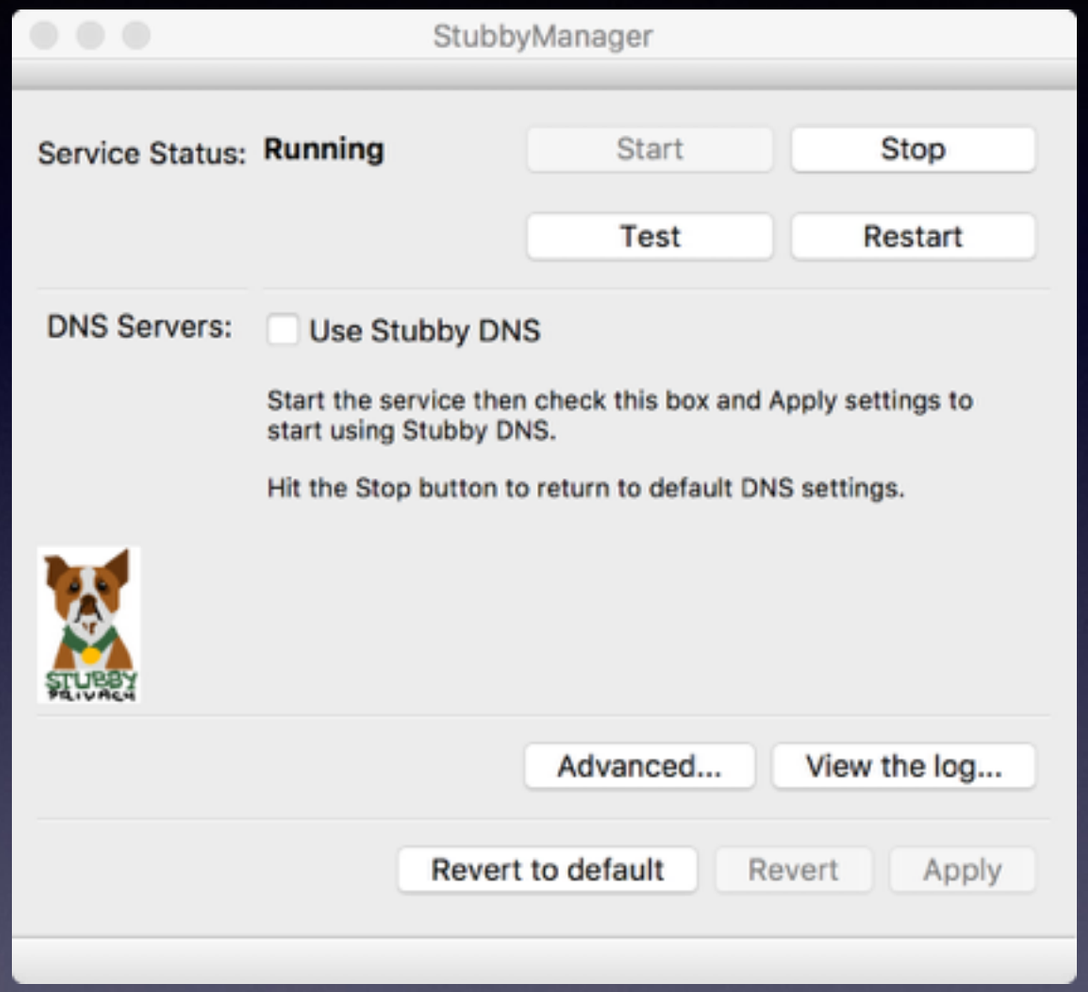
Stubby Status

- Command tool still prototype - for ‘advanced’ users
  - Supports name and SPKI pinset authentication
  - Strict and Opportunistic profiles
- **Being split out as a <u>separate application</u>…. (WIP)**
- Homebrew formula, docker image and macOS UI on the way…..

CLIENTS

Prototype!
HELP WANTED

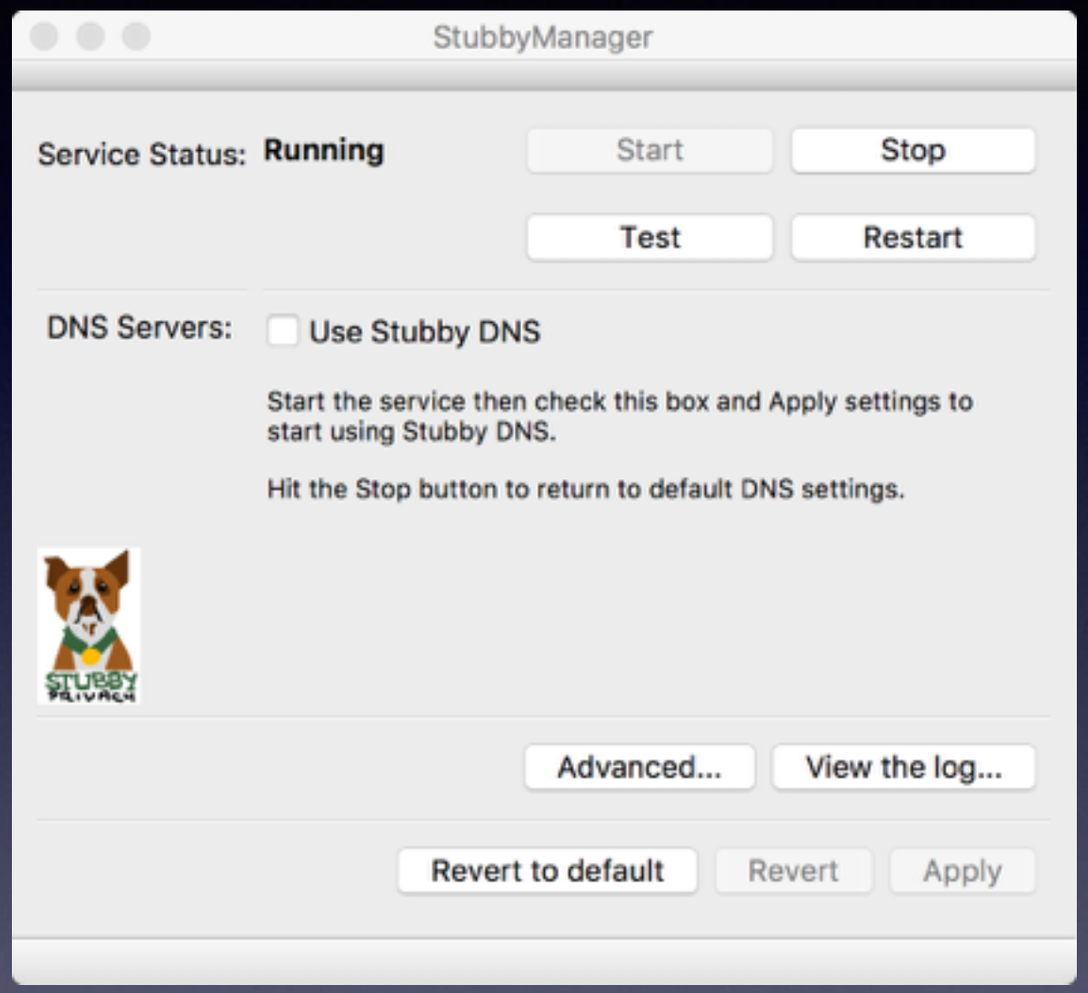
SubbyUI preview

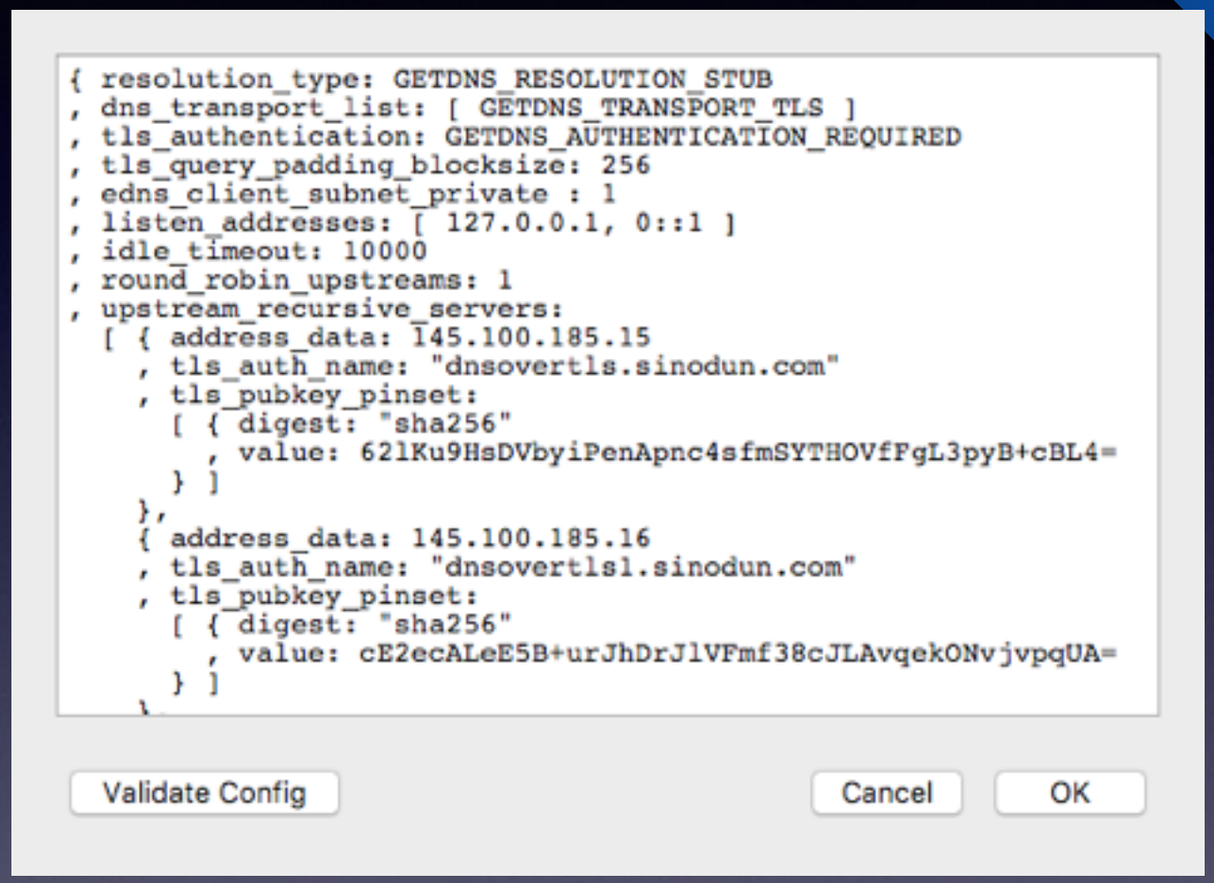


CLIENTS

Prototype!
HELP WANTED

SubbyUI preview

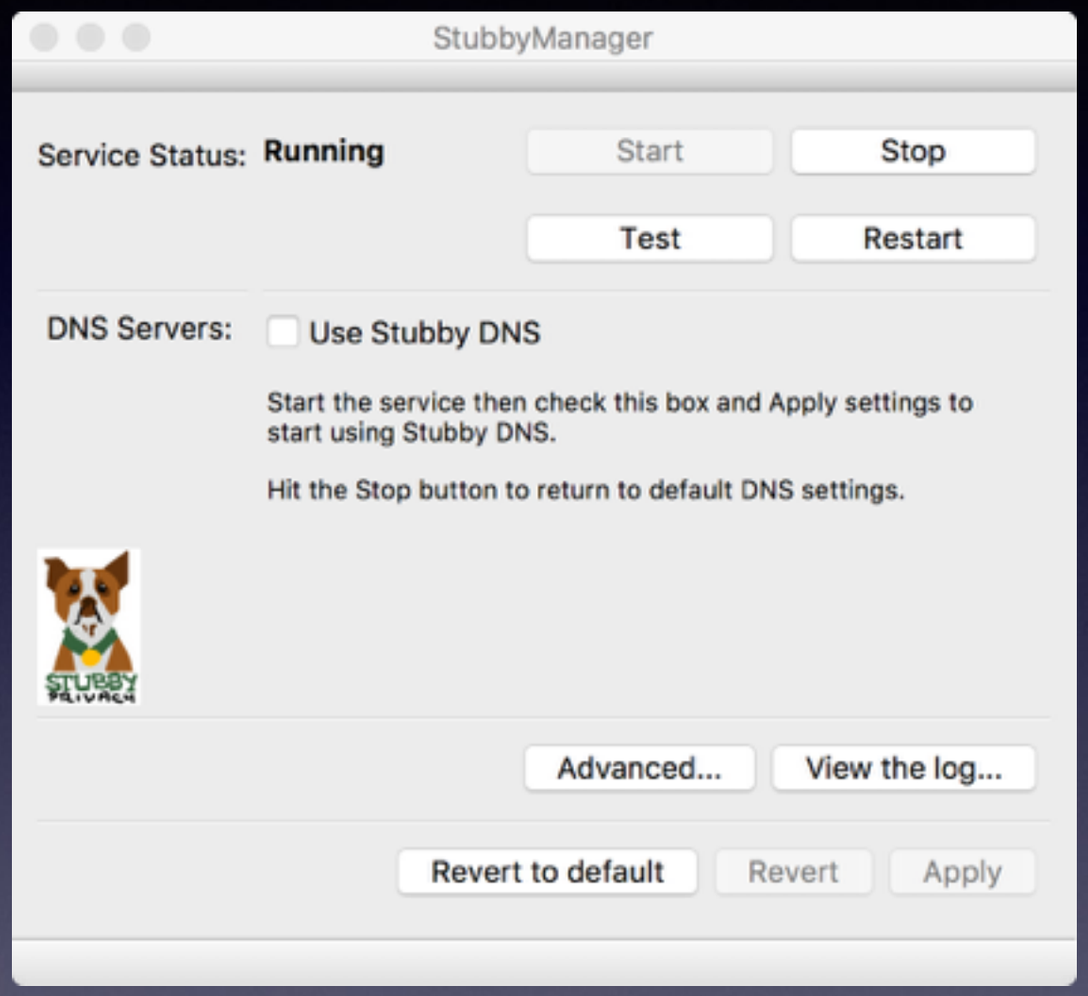


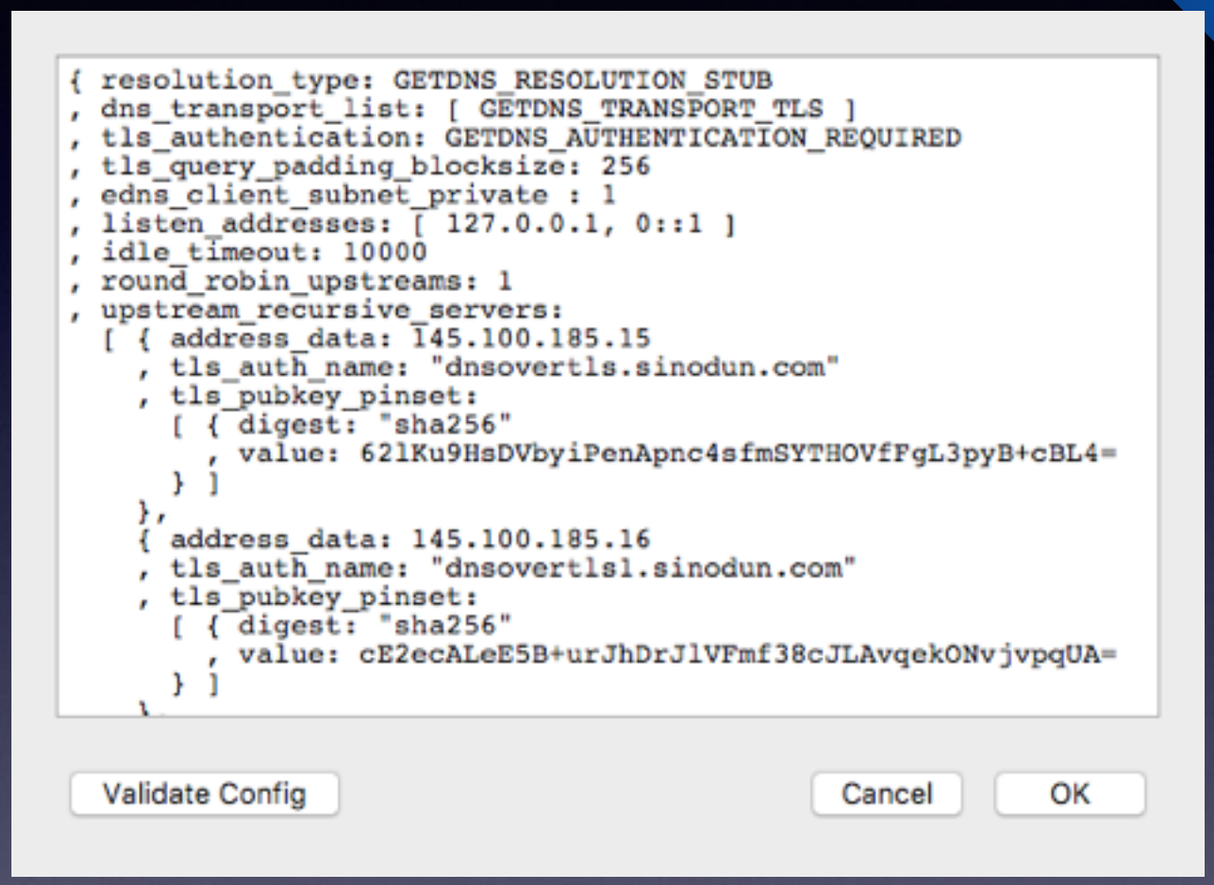


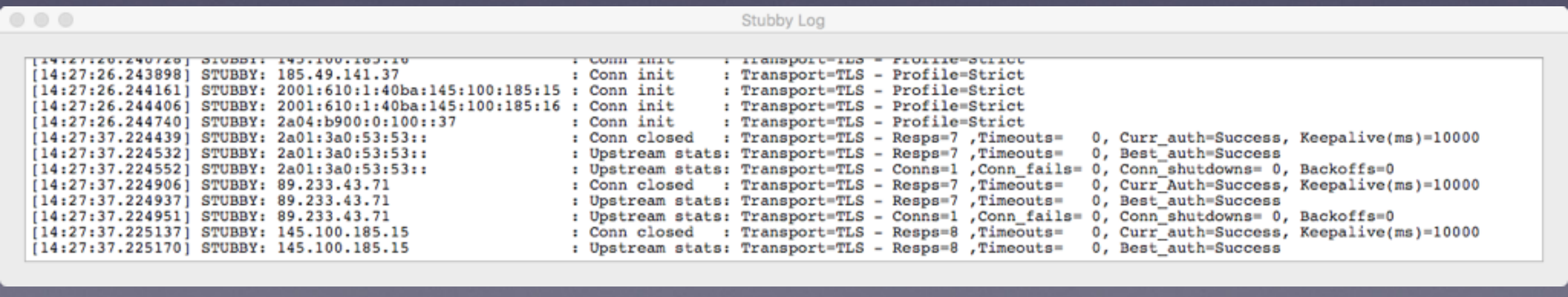
CLIENTS

Prototype!
HELP WANTED

SubbyUI preview







Hackathon news…

- More work on Stubby packaging and UI
- Implementation started on Dane Authentication in getdns and Unbound
- Android support for Opportunistic DNS-over-TLS is a work in progress

DNS Privacy Usability

- DNS Privacy is a new paradigm for end users
- End users are a new paradigm for DNS people!

- '**Usable Security**': Good GUIs aren't enough - users still struggle with the basics if they don't understand what they are doing (HTTPS, PGP, DNSSEC)

- DNS Privacy uptake critically dependant on clients being usable + successful

Key challenges

1. Awareness!
2. Clients: OS integration of (more) client solutions
3. Usable client solutions for non-technical users
4. Increased deployment (anycast deployments)
5. Operator transparency in DNS data handling
6. Recursive to Authoritative….

Summary

- DNS Privacy is a real problem and more relevant than ever
- Active work on the large solution space
- Can use DNS Privacy today using Stubby & current experimental recursive servers
- More DNS Privacy services on the way…

Thank you!

Any Questions?

dnsprivacy.org